Published monthly by the

New York State Education Department

BULLETIN 353 OCTOBER 1905

New York State Museum

JOHN M. CLARKE Director

Bulletin 95

GEOLOGY 9

GEOLOGY OF THE NORTHERN ADIRONDACK REGION

BY

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ALBANY

NEW YORK STATE EDUCATION DEPARTMENT

1905

M149m-S4-2000

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INTRODUCTION

The writer's work in the Adirondack region has been mainly confined to Clinton and Franklin counties, and what is set forth in the present report is mainly the result and summation of that work. In addition some detailed investigation has been done in western St Lawrence county and in the region about, and northward from, Little Falls in Herkimer county. Brief reconnaissance trips have also been made in Essex and Hamilton counties. Professors Kemp and Smyth have worked during the same period in other parts of the region. They were the pioneers and generously made room for me. We have all worked most pleasantly and harmoniously together and in consultation, in correspondence, and in combined work in the field have freely shared ideas with one another. How large a part of my present views concerning the geology of the region is due to this free intercommunication, I am wholly unable to say. I only know that the indebtedness is great, is fully appreciated and gratefully acknowledged.

The Adirondack region is in many respects a difficult one in which to study geology. The universal forest covering, the difficulty of getting about, greatly increased in burned districts and in those littered with the lumberman's refuse, the frequency of rains and the scarcity or absence of settlements in most of the district are hindrances to work in many respects, specially since

the complicated character of the geology necessitates a careful survey of the whole ground. The work has been greatly hampered also by the very imperfect character of the maps available, the new maps as yet barely reaching the region under consideration. The healthful and invigorating climate and the abundance of pure water are great compensations in their way.

The problems presented for solution are of the most difficult sort. The interpretation of the present topography, the working out of the complex history of the region during Glacial times and the deciphering of the complicated structure and history of the older rocks of the region are all matters requiring long and patient labor and the undivided attention of the worker. The writer's attention has been centered mainly on the latter problems, hence such work as has been done on the others has been incidental, and the fragmentary character of the results obtained is fully appreciated. Prof. J. B. Woodworth is now occupied with these matters, and, when his work is extended over the immediate region, great and important additions to our knowledge are sure to follow.

The summary of the geologic history of the region with which the report opens is for the convenience of the reader. The detailed evidence on which that summary is based will follow later and must be taken for granted till presented.

SUMMARY OF GEOLOGIC HISTORY

The rocks now exposed at the surface in the Adirondack region proper, are among the most ancient rocks known anywhere on the earth's surface, so that their record carries us far back, back to the remoter times of the geologic history of the earth. This early record is exceedingly difficult to decipher because of the great age of the rocks, because of the fact that they have been vastly modified in character by repeated action of great compressive forces, and because the rocks now at the surface were, at an early stage in the history of the region, deeply buried under several thousand feet of other rocks which have since been worn away. It was while thus deeply buried that the major part of

this change from their original character was effected. But the character of the change brought about by compression varies with the depth of the rocks beneath the surface because of hightened temperature and pressure, and rocks may become so greatly modified as to lose all trace of their original character.

Precambric history

Old sediments. The oldest rocks which have with certainty been recognized in the Adirondack region consist of certain well banded gneisses and schists, with bands of varying thickness of coarsely crystalline limestone. They are believed to be old water-deposited rocks, ancient sheets of sand, mud and calcareous mud, deposited on the floor of some large body of shallow water, in all probability the sea. They are now so greatly changed from their original condition that the structures and textures characteristic of rocks so formed have been almost wholly destroyed, being replaced by others which are not characteristic, since they may be produced in igneous rocks as well. The inference as to their original condition is based partly on their composition, and partly on the fact that they show frequent and rather abrupt alternations in character, as if they had originally consisted of beds and layers of varying composition, as water-deposited rocks do. There is apparently a great thickness of these beds, but their base has never been made out with certainty nor is their summit known, so that our ideas concerning their thickness are of the vaguest. They must have been laid down on a surface of older rocks; but we are at present wholly in the dark as to whether or not these older rocks are anywhere exposed in the district at the present time. Rocks which may not improbably represent them, are present and will be shortly described, but no exposures which will enable a decision in the matter have been discovered, nor are they likely to be in the immediate district, though perhaps such may be found to the west or south.

Though unknown, the thickness of these deposits is great, with repeated changes in character, so that it is beyond question that the submergence endured for a long, a very long time, during

which many changes in conditions occurred, as shown by the changes in character of the rocks.

Closely involved with these rocks are others which would seem to be of ignéous origin, so far as may be judged from their composition. The great changes which they have undergone have destroyed their original characters utterly, and they have been stretched out into bands parallel with the associated sediments, causing them to appear as an integral part of the series. It seems quite certain that they are, in part at least, igneous, and that they must be somewhat younger than the sediments, except in so far as they may possibly represent subaqueous surface flows; yet they can not be greatly younger, since they have undergone much the same changes, both in kind and in degree, that the sediments have experienced. Wherever the sediments occur, these igneous rocks are sure to be found associated with them, thus indicating widespread and profound igneous activity at the time.

Rocks of doubtful age. In many parts of the region, and running in a broad belt across Clinton and Franklin counties, is found a group of old rocks, profoundly changed from their original condition, which seem to be wholly of igneous origin, so far as can be judged from their composition; at least no rocks similar to those of the preceding group and which are judged to be sediments occur with them. They have been equally, if not more changed from their original condition than have the rocks of the preceding group, and all traces of their original structures have been destroyed. It is by no means impossible that they are older and represent the rocks of the floor on which that group was laid down; indeed, if any remnants of that floor remain, we have them here. But, since similar rocks, in general not to be distinguished from them, occur associated with the sediments, where they are clearly as young, or younger, these may represent great masses of such rocks, massed in such amount as to have wholly displaced the sediments. We are not able to decide these questions as yet. If but one rock group is represented, it is no older than the sediments. If more than one be present, one may be older. But, if so, we as yet lack the means of discriminating between them.

The rocks at present found in the district embrace only a fragmentary remnant of those formed at this early time, a great thickness of other rocks having been laid down above them and later worn away. Twenty thousand to twenty-five thousand feet is not an exaggerated estimate of this thickness. It is not meant to imply that a uniform amount has been removed from the whole district, in fact there is every reason to believe that the opposite is true, that the region has been for much of its history a rugged one, and that much greater removal has taken place from the hights than from the depressions. While this accumulation of the rocks which have since disappeared was in progress, the region was in all probability below sea level and keeping pace with the deposit by a slow subsidence. Not improbably a great part of the accumulated thickness consisted of igneous rocks.

Great igneous intrusions. After the present surface rocks had become deeply buried, they were invaded from beneath by a series of great igneous intrusions, broken up into patches and no doubt pushed upward to a considerable extent. At the time of the appearance of these intrusions the previous rocks had become profoundly changed in character, so that they were much in their present condition. The district embracing Essex, southern Franklin and northern Hamilton counties felt the full force of this invasion, the larger part of the present surface rocks in that district consisting of these igneous rocks, while away from it they occur merely in patches. The present rocks cooled far beneath the old surface and have been brought to the present one by wear and removal of the overlying rocks. They represent abyssal, cooled masses, whence no doubt much molten material ascended toward, and not improbably to, the old surface.

These rocks may be grouped into four great classes, anorthosites, syenites, granites and gabbros, all undoubtedly derived from some great parent molten mass below by some process of differentiation. The' anorthosite intrusion was the first, the bulkiest, and is the only one whose precise limits have so far been worked out. It was followed by one of syenite, that by one of granite, and the gabbro intrusion seems to have been latest of all.

All three have a much wider range and a more patchy distribution than the anorthosite. Their precise importance is however uncertain, since there are certainly granites and gabbros, and likely syenites also, of more than one age in the region, though quite similar to one another, so much so that no criteria have yet been developed for their discrimination. This difficulty has not to be met in the case of the anorthosite.

At some time after the cooling of these great intrusions the whole district was subjected to great compression, as a result of which all the existing rocks were profoundly changed in character, the intrusives as well as the older rocks. But, since the igneous rocks did not experience the earlier compressions, as did the others, and since these must have been profoundly affected by the heat and pressure of the intrusions themselves, the intrusives are less completely altered than are the older rocks, and frequently retain traces of their original structures and textures, often in considerable amount, so that usually their origin and nature are not open to question. This is specially true of the anorthosites, which are mostly very coarse grained, porphyritic rocks, but it is frequently true of the others also. The rocks were more or less mashed and recrystallized, and rendered gneissoid in greater or less degree, the same rock varying much from place to place in these regards. It is the more gneissoid phases which are most difficult to distinguish from some of the older rocks.

The character of the changes produced indicates that the rocks were under great load during the compression, or, in other words, were deeply buried beneath overlying rocks.

Great Precambric erosion. Precambric time was very long, not improbably comprising as much as or more than one half of the earth's geologic history. During most or all of the later part of this vast time interval the region was a land area and undergoing wear. The overlying great thickness of rock under which the present surface rocks lay buried at the time of compression, was removed in Precambric time in greater part. Quite likely the time of elevation into a land area coincided with the time of compression, the two being effects from the same cause. The great

igneous intrusions may also have aided or initiated the upward movement. The great thickness of rock removed indicates the probability of more than one upward movement, since it is unlikely that the region ever had an altitude equal to the bulk of removed rock. Periods of depression beneath the sea may have alternated, though it is improbable that these could have had any great duration, or we should surely find traces in the region of the deposits formed, and these we do not find. It is impossible to state positively the amount of rock removed during this great denudation, but in all likelihood at least from 3 to 5 miles of rock thickness were worn away from the surface, and perhaps considerably more, specially locally.

Surface topography at the close of the erosion interval. The land surface left at the termination of this long period of wear is of such nature that it could have been produced in no other way than by long protracted erosion under conditions of stability of level. After the last uplift of the region the streams sawed their valleys down to grade; and the slow processes of valley widening continued at their work of broadening the valley bottoms and narrowing the upland divides between the valleys, till the latter were largely obliterated, and the resulting surface was one of small relief, broad, shallow valleys, largely adjusted to the weaker rock beds and structures, separated by low, gently sloping divide ridges, with occasional low, rounded hills of extraresistant rock protruding above the general level, with elevations of only a few hundred feet above the valley floors as a maximum. To produce a land surface of this sort, specially on such resistant rocks as those of the Adirondacks, requires a vast lapse of time. The surface was not equally planed down in all parts of the region, but was somewhat more irregular on the present northern and eastern borders than on the southern and western, though the discrepancy is not marked. Over much of the surface the rocks were deeply weathered and decayed, forming a deep soil, but the evidence in this regard is conflicting, and apparently decay was less advanced on the northeast than elsewhere.

Later Precambric disturbances. During the long Precambric erosion period the present surface rocks were gradually approaching the surface as the overlying rocks were, bit by bit, removed. They were therefore under progressively less and less load of overlying rocks, and, if subjected to compression during this stage, the effects produced would be very different from those brought about by compression under great load. That the rocks were so affected when much nearer the surface is clear, the main result being the production of the highly inclined or vertical, rather even cracks or fissures known as joints. There have been later times of joint formation in the region also, and the different sets are difficult of discrimination. But it is clear that there was some development of joints and faults, indicative of stress, at this time.

Late Precambric igneous activity. During most of the long period of denudation which followed the time of the great igneous intrusions there was an absence of igneous activity in the region, at least in so far as near surface effects were concerned. But toward the close of the period, when the present surface rocks were no longer deeply buried, but were comparatively near the surface, molten rock again came up from beneath, likely from the same source whence the material of the great intrusions sprang. Whether any of this molten rock reached the surface then existing can not be determined, since no vestige of that old surface now remains, but in all probability there was volcanic action at the surface. The lavas utilized a system of east and west fissures or joints as their channels of ascent and eventually cooled and solidified in them. Such lava-filled fissures are known as dikes, and these dikes are very numerous in portions of the region, specially at the northeast. Their upper parts, along with their surface outpourings, were worn away long ago. Could they be followed in depth, they would lead eventually to the reservoirs which supplied the material with which they are filled.

There are two sets of these dikes, showing that there were at least two separate periods of igneous action at the time. The more common dikes are of heavy, dense, black rocks of the sort known as diabase. The others are less dense and heavy, usually

of red color and have the composition of syenites and granites. The latter are somewhat the older. The northeastern Adirondacks were the main scene of this igneous activity. The red dikes are practically confined to Clinton county. The black dikes are much more numerous and have a much wider range, but are vastly more abundant in Clinton and Essex counties than elsewhere.

Erosion still continuing after the close of the igneous activity, all vestiges of the surface volcanics disapppeared, along with a thickness of rocks of considerable amount, but to be measured in hundreds, rather than in thousands of feet.

Early Paleozoic history

The long period as a land area finally came to an end, a movement of subsidence was initiated in the region and it became depressed, slowly passed beneath the level of the sea and began to receive deposit on the rather evenly worn surface, the valley bottoms necessarily passing beneath the sea before the low divides were overtopped. This subsidence began at the northeast and slowly progressed southwestward. As zone after zone came within reach of the cutting of the waves, they would tend to pare it away to a smooth surface, and in parts of the region this wave action may have been a considerable factor in evening it. As zone after zone passed beneath the sea, deposit would commence on the surface, and, as the subsidence began on the east and northeast and progressed westward and southwestward, deposits of progressively younger and younger age appear resting on the old land surface in passing from east to west, producing what is called overlap. Because of this, the earliest paleozoic deposits, those of Lower and Middle Cambric age, do not appear about the Adirondack region at all, though found not many miles to the eastward, where they were deposited in a separate basin. Because of this, the Potsdam formation, or Upper Cambric age, does not appear on the west and south of the Adirondack region, though in great force on the north and east.

Potsdam formation. This coarse, often pebbly, massive sandstone deposit was the first formation laid down on the old land

surface of the present Adirondack region. It was deposited in shallow water under conditions of sufficiently vigorous wave and current action to remove all fine mud particles, which were swept away and deposited elsewhere in deeper water. In Clinton county a thickness in excess of 800 feet, perhaps more than double that amount, of this sand accumulated before changing conditions brought about a change in the character of the deposit. The water must have been shallow throughout, hence the rate of subsidence could not have exceeded the rate of accumulation. This thickness diminishes westward and southward, and the sands are mostly absent from the west side of the region, as has just been stated. With diminishing thickness, it is apparently the lower beds that disappear. The basal portion of the formation in Clinton county seems to be the oldest of the deposits in the Adirondack region, and its often coarsely pebbly character and abundant content of undecayed feldspars indicate vigorous wave action on rocky shores of resistant, unrotted rocks. The upper portion of the formation here, and most of it elsewhere, consists of pretty pure quartz sand, indicative of prevailing different conditions from those above, namely that either the feldspars had been pretty thoroughly rotted previous to submergence, or else that they experienced the triturating action of the waves for a sufficient length of time to be wholly ground fine, while the somewhat harder quartz yet remained coarse, implying a slower rate of subsidence. The former is much the more probable cause, though no doubt the latter had some influence also.

The present Adirondack region must have supplied much of the rock material thus spread on the sea floor, and the drainage of the district must have been mainly to the north and east. The present western border of the region was but slightly submerged during this time, and for part of the time the waters were clear, with deposit of limestone instead of sand. The upper part of the formation around the Adirondacks is certainly a marine deposit and holds marine fossils. These are lacking in the larger part of the formation, and this, together with its character, sug-

gests the possibility that the larger part of the formation on the north was deposited in a closed or nearly closed basin.

Beekmantown formation. By the close of Potsdam time the sea had encroached for a considerable distance on the present northern and eastern portion of the Adirondacks, but there was yet a large land area remaining in the heart of the region which on the west and southwest extended somewhat beyond the present surface limit of the Precambric rocks in these directions. During Beekmantown time submergence was in progress on all sides of the Adirondacks, but it was most rapid, and to greatest amount on the northeast and diminished to the south and west, the rocks having treble the thickness in the lower Champlain valley that they have along the Mohawk. On the extreme west the amount of subsidence was but slight and little deposit took place.

The Beekmantown rocks are in large part peculiar, and except for the fact that they are clearly water-deposited rocks, the precise conditions under which they were deposited are difficult to understand. In the upper portion of the formation are many pure limestone beds, often containing numerous fossils, and so far as these are concerned the formation seems clearly a marine limestone. These beds seem to be limited to the east and north sides of the region and to be wholly lacking on the south and west. The bulk of the formation everywhere is made up of beds of sandy dolomite. The sand is mostly rather coarse and is embedded in a fine mosaic of crystalline dolomite. There is little mud in the formation and fossils are either wholly lacking or else exceedingly rare. The sands imply vigorous water action, sufficiently so to transport them to their present resting place and to wash away all fine mud. Yet the sand forms less than 25% of the whole formation, the bulk being dolomite, along with some calcite. The nature of the deposit would suggest a chemical, rather than an organic origin for this material, since the waters must have been shallow, and this would imply estuarine or closed basin conditions of deposit, stream waters holding lime

and magnesium carbonates in solution, with frequent storm waters sweeping in sands from the adjacent land, and likely a climate of some aridity. That is, there must have been a land barrier to the eastward separating the basin from the Atlantic, and another to the westward shutting it off from the interior sea, with a considerable Adirondack island in the midst of the sea, on whose slopes the different beds of the formation overlapped as subsidence progressed. The whole subject is beset with difficulty and needs thorough investigation, something that it has not yet received.

Because of the greater thickness of the formation in the Champlain valley, and because the upper marine limestones occur only there and on the north, it is reasonable to suppose that the subsidence here opened a northeasterly connection with the sea, whence the marine forms entered the basin. Likely at about the same time subsidence ceased on the south and west and was not improbably replaced by uplift, raising the region above sea level and preventing the deposit of the marine limestones there. Such an uplift certainly occurred shortly after, and may well have begun then.

As a result of the Beekmantown subsidence and deposit, the land area of the Adirondacks was much diminished in size; though there still remained an area, mainly on the south and west, which was not submerged. Then came the uplift, which much increased the extent of this land to the south and west.

Chazy formation. In the Champlain valley the Beekmantown formation is overlain by a considerable thickness of mostly quite pure, marine limestone beds containing abundant fossils. Followed to the north into Canada, these deposits change into sands and muds to a considerable extent, showing that a land area which supplied this land wash must have existed in that direction. How much of the present northern Adirondack region was overspread by the Chazy sea can not be told, but it would seem that it must have been mainly submerged, since no land wash from it reached the present Champlain valley region. Followed to

the south, the Chazy deposits rapidly thin out, and the formation was not deposited on the south and west sides of the region at all. Subsidence thereabouts must therefore have intermitted during Chazy time and likely during the latter part of Beekmantown time as well. In fact, the downward movement seems to have been replaced by one in the contrary direction, bringing above sea-level an area of considerable, though unknown, extent to the south and west of the Adirondacks, a condition in which it remained throughout Chazy time. The altitude above sea-level must have been very slight, since the surface shows little sign of wear.

The Chazy basin then spread over the north and east sides of the region only, its open water connection being with the eastern, and not with the interior sea, the extent of the latter being considerably contracted during this time.

Lowville limestone. This is a comparatively thin band of pure limestone which directly overlies the Beekmantown on the south and west sides of the Adirondacks, but does not appear at all on the north and east. The Chazy elevation on the southwest was terminated by depression, and at about the same time or previously, elevation occurred, draining the sea from the Chazy basin. The Lowville is plainly unconformable to the Beekmantown surface, varies much in thickness and is wholly wanting in places, evincing the irregularity of surface on which it was laid down.

The conditions under which the Lowville was deposited did not permit the entrance of, or else were unfavorable to the life of a marine fauna. If the former be the explanation, there must have been a land barrier between it and the sea to the south; if the latter, the cause is purely conjectural. Certainly the rock is very barren of fossils for the most part.

Black River and Trenton formations. Both the Chazy formation on the northeast and the Lowville on the southwest are overlain by a series of limestone beds which are plainly of marine origin, showing that following the Lowville, subsidence was

inaugurated all about the Adirondacks causing the interior sea to spread northward and eastward over the entire region. The Black River is locally absent along some of the southwest border, owing to slight irregularities in the floor on which it was laid down, and less frequently some of the basal Trenton is absent from the same cause. Whether these irregularities were due to wear or to slight folding has not been determined.

While apparently some slight remnants of the old Adirondack island persisted above sea-level during the whole or part of the Trenton, it is probable that they were of insignificant extent and likely confined to the southern part of the region. With these possible exceptions the sea of the closing Trenton seems to have overswept the entire Adirondack region.

The Black River and Lower Trenton are quite pure limestone deposits and hence clear water formations. But the Trenton soon comes to show some mud admixture, at first slight and intermittent but slowly increasing in amount, till finally it equals and then exceeds the lime, and the deposit becomes a calcareous shale rather than a limestone. These muds came from some land area to the eastward and progressively invaded the sea toward the west, so that limestone was still in progress of formation on the west while shales were forming to the east.

Utica formation. The limestones of the Trenton pass gradually upward into shales through increasing invasion of mud from the east. Trenton submergence was much interrupted on the south and southeast, so that the formation is much thinner there than on the west and the northeast. In the latter locality the greater thickness is likely due to more rapid, or to less interrupted subsidence. On the west it is, at least in part, due to the gradual encroachment westward of the muds. Eventually however the conditions of mud deposit held sway over the entire region and far beyond. The sea was not deep, and the muds were swept in by currents moving toward the southwest. Subsidence was considerable, so that several hundred feet of shales accumulated in nearly all parts of the region, and in some portions a much greater thickness.

This submergence apparently completely overswept the old Adirondack island, and that for the first time in its Paleozoic history, with the possible exception of the latter part of the Trenton. The whole of New York State would seem to have been submerged and that for the last time in its geologic history.

Later Paleozoic changes of level

Toward the close of Utica time subsidence became again interrupted and an upward movement was initiated. It was first felt on the northeast, bringing the northern Adirondack region again above the sea, and it has in the main remained a land area from that time to the present. The movement of elevation progressed to the south and west till all of eastern New York had been brought above sea level. From this time on the oscillations of the southern and western borders of the present Adirondack region now admitted the sea to unknown distances on the flanks of the region, now again excluded it. Thus the Medina, Clinton and Helderberg seas of the Siluric and Devonic quite certainly overlapped the margin of the region to some extent, and later Devonic seas may well have done likewise. The district was near the shore line of those seas, alternately received deposit and experienced wear as the position of the shore line fluctuated. The truncated edges of the deposits of those seas now come to daylight to the south of the Mohawk valley in successive order of deposit, their formerly existing extensions northward having been worn away. Hence, while it is obvious that they formerly extended considerably north of their present limits, the amount of such extent is purely a conjectural matter.

While the sea border was hugging the south and west sides of the region, the remainder was out of water and so continued with the possible exception of the submergence of a Champlain valley strip during Helderberg time. Such a submergence is very probable, but the amount of area so depressed is purely conjectural, the deposits of the time having utterly disappeared, owing to subsequent erosion. This is, so far as known, the only time that any portion of the northern Adirondack region has

been beneath the sea since the close of the Utica, except for a submergence of the Champlain valley in very recent times. In all likelihood it was a depression of a channel, rather than of a wide area.

Paleozoic disturbances

Aside from the repeated oscillations of level in the region during Cambric and Siluric times, which have just been outlined, there were periods of more considerable disturbance. Following Utica deposition and uplift there came such a time. Compression acting from the east effected the elevation of the Taconic range with some folding and fracturing of the rocks, and in a minor way the Adirondack region was affected. Again toward the close of the Paleozoic the stresses which produced the folding and uplift of the Appalachian region must have been felt in this region also. Not unlikely there were other times of lesser stress. The effects produced on the rocks of the region during these various times were the same in kind, and, though the sum total of all can be recognized, the relative amount to be ascribed to each period can not be ascertained. The main results were the production of faults and joints in the rocks.[1] Minor undulations, or folds, were also produced, but these are relatively insignificant and entirely subsidiary to the other effects. The eastern Adirondack region by no means felt the full force of either disturbance, and in the west the effect was much less than in the east. The major line of both disturbances swerves round, and approaches the region most nearly at its southeast corner.

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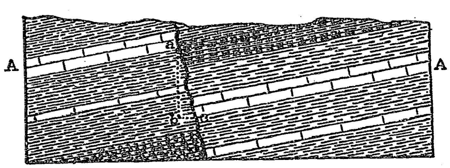
[1] A fault is produced by a sliding movement of the rocks on opposite sides of a fissure, with the result that the same rock stratum is higher on one side than on the other, as illustrated in the accompanying diagram. The stratum AA has been dropped on the right side of the fault relative to its position on the left side. The distance *ac*, measured along the fault plane, is called its *displacement*, the vertical distance *ab*, that separates the two ends of the stratum, is called the *throw*, and the horizontal distance *bc* is the *heave* of the fault.



The main faults of the region run across it with a general n.n.e.-s.s.w. course, but they curve repeatedly, and a given fault seldom holds a given direction for any great distance. In nearly all cases the dropped block is on the east, and the raised block on the west side of the fault plane. The resulting topography must have consisted of relatively narrow platforms terminated westward by cliffs of varying hight, depending on the throw of the fault concerned, rising to the level of the next platform above, the whole with a general n.n.e.-s.s.w. trend. Thus seems to have been produced for the first time the considerable and rather abrupt difference in level between the Adirondack region and the Champlain valley. The eastern Adirondack region was thus given a considerable elevation, with a rapid, steplike fall to the eastward and a gentler and steadier slope to the west.

Some few of the faults downthrow to the west instead of the east, producing between such a fault and the next easterly throwing fault to the westward a depressed block or valley with steep inclosing walls on both sides.

In addition to the main faults are a multitude of minor ones grading down to the merest slight slipping along the joint planes. Many of these are cross faults of considerable magnitude, making large angles with the main ones, and cutting up the main platforms into a series of segments at various levels.

It is likely that most of these faults date from the time of the Appalachian uplift of the late Paleozoic. A beginning may have been made by the Taconic disturbance.

Paleozoic igneous activity

Initiated possibly by the disturbances which effected the elevation of the Taconic mountain range, though more likely of late Carboniferous date, came renewed igneous action. Here again all traces of surface volcanic action, if there was such, have been removed by subsequent wear, and the only signs of the activity which remain are the old, lava-filled channels of ascent, the dikes, together with a few larger masses, which paused before reaching the surface and crowded out a place for themselves by squeezing

laterally between the rock layers, and bodily raising the overlying rock. Here again we find two sharply contrasted sorts of lava, one light colored and difficult to render thoroughly fluid, the other black and fusing at a much lower temperature. Here again the black rock is much the more abundant and with wider distribution. But here such evidence as there is shows that the black rocks were the first, instead of the last to appear, as in the case of the late Precambric dikes.

In New York these rocks are confined to the near vicinity of Lake Champlain, in Essex and Clinton counties. Apparently the Adirondack region was on the extreme edge of the district affected.

In the Mohawk valley and westward, occasional dikes are found of a very different character from those along Lake Champlain, which are perhaps younger than they are and represent intrusions from a different source. They are so few in number and so scattered that they indicate only a trifling amount of igneous activity. If there can be said to be any well marked center of action at all, it was about Syracuse. If there were any surface volcanos, they must have been few and small.

Paleozoic erosion

Throughout the latter part of the Paleozoic the Adirondack region was a land area, and, if the assumption that a considerable amount of the faulting of the region dates from the time of the Taconic disturbance be correct, this land area had a considerable elevation on the east and northeast, diminishing gradually to the west and south, with the Champlain valley outlined as a result of the faulting. The time involved is great, several millions of years at least, and a large amount of erosion must have been accomplished, specially on the more elevated areas. The cover of paleozoic deposits must have been swept away over a considerable portion of the interior region, where it was thinnest, and the general surface much evened by erosion. So far it has been found impossible to separate this erosion interval from that which followed, so far as results are concerned. All of the surface left by

the former seems to have been removed later, and it can be simply inferred that much wear took place. In all probability the great Appalachian disturbance, near the close of the Paleozoic, must have been strongly felt, causing renewed movement along the fault planes provided they were in existence, and a considerable increase in the altitude of the region.

Mesozoic history

During early Mesozoic times there were disturbances of considerable amount in the eastern part of the country, whose effects may well have been felt in the Adirondack region. A subsidence of long, narrow troughs, parallel to the general trend of the Appalachians, took place; deposits accumulated in these troughs, often to very considerable thickness; large quantities of quite fluid igneous rock ascended from below, in part reaching the surface as great flows, in part thrusting a way between layers of the accumulated sediments as interbedded sheets; faulting on a large scale followed, breaking up the surface into a great mosaic of fault blocks. It is quite possible, nay probable, that further movements took place along the Adirondack faults at this time, and additional faults may have formed. It is also possible that, because of downfaulting, deposits may have accumulated in the Champlain and upper Hudson valley troughs. Evidence has recently been forthcoming of volcanic action, probably of this date, on the immediate southeast margin of the Adirondack region, and the future may bring to light similar evidence elsewhere.

However this may be, the further faulting would have produced additional elevation of the Adirondacks with increased altitude above the Champlain valley, and inaugurated another period of active erosion tending toward a new and lower base level. On the mosaic fault blocks of the valley the amount of possible erosion would largely depend on relative altitudes, and great variation in the amount is to be noted on adjacent blocks, Potsdam, Beekmantown, Chazy, Trenton and Utica rocks, even Precambric as well, all being found as surface rocks near the lake level today, often in close proximity. Where Utica rocks are at the surface, the

total amount of wear since Utica time has been exceedingly small, and the surface must have been for much of the time near base level. Moreover, such blocks were the most downfaulted of all and must have formed depressed basins with every period of renewed faulting, as such receiving deposit from the surrounding higher blocks as these were worn down, thus protecting their own surfaces from wear for long intervals.

This erosion interval was so protracted, extending through the greater part of Mesozoic time, that the whole region was finally planed down to a surface of little relief, broad shallow valleys and low divides, with occasional low, rounded hills or clump of hills where extraresistant rocks occurred, or where favorable location prevented maximum wear. The fault cliffs, or scarps, were entirely wiped out as topographic features, the raised side being worn down to the same level as the dropped.

In the southern and western Adirondack region this old surface is still recognizable, as the upland surface into which the present valleys are cut, the old residual hills rising above it now as they then did. The present plateau upland of southeastern New York would seem to represent a continuation southward of this same old surface; and, if this be the case, the result in the Adirondacks was simply a local development of conditions which prevailed widely in the eastern United States at this time.

Cenozoic history

This long period of quiet wear was terminated by another uplift, which would seem to have occurred at the close of Mesozoic, or the beginning of Cenozoic time. This uplift inaugurated another erosion cycle with a much lower base level. In the Adirondack region this uplift was, at least for the northern part of the district, of a dome-shaped character, the major axis of the dome being along a nearly north-south line closely coinciding with the line between Clinton and Franklin counties, thence turning southwestward; the minor axis running through the extreme south of Franklin county and thence eastward through Essex. In the eastern Adirondacks this uplift was complicated by further shifting along the fault planes, bringing fault cliffs, or scarps, again

into prominence as topographic features; reelevating anew the eastern region as contrasted with the Champlain valley, and reproducing the comparatively rapid, steplike drop from one to the other; and breaking up the old, comparatively even erosion surface into a jumble of disconnected blocks at various altitudes. Hence the present ridge and hilltops appear at all sorts of discordant elevations, instead of exhibiting the concordance in altitude which is such a characteristic feature on the south and west, where there was little or no faulting.

Not far to the west of the main axis of uplift lies a central depressed belt whose ridge summits fall far short of attaining the elevations along that axis, and much short of attaining those to the west. These differences are most accentuated through Franklin county, and the belt seems to have originated as a depressed, or dropped fault block, between the eastern and western uplifted areas. Whether it originated at this time, or dates back to a previous period of faulting, with renewal of its previous features at this date, can not be told.

The region remained at the new altitude given by the uplift for a sufficiently long time (the greater part of the Cenozoic) to permit of erosion giving it approximately its present relief. Stream valleys were cut down to the new base level and on the average sufficiently widened, so that one half of the region (at a rough approximation) was cut down well toward that level, the remainder forming interstream ridges and hills whose summits have been lowered little below the altitude given them by the uplift. The streams had become adjusted to the rock structure of the region during the previous cycles of erosion, so that they coincided with, and their attack was mainly felt on, the weaker belts. In the heart of the region, where Precambric rocks are at the surface, the weaker rocks are the Grenville limestones and associated sedimentary gneisses. Wherever these rocks occurred in belts of any extent, they would locate the line of a stream valley, whose width would be rudely proportional to the breadth of the belt. The remaining common rocks of the region are much more resistant and with no great variation among themselves in this respect, so that they present little compara-

tive inducement to valley-making, and the principal remaining lines of weakness are structural, lines of faulting and of repeated jointing. The main joint directions vary somewhat in different parts of the region, but there is always an important set with a direction approaching parallelism with that of the main faults, and many of the main valleys of the region have this trend, this being specially noteworthy in the eastern district where faulting has been most pronounced.

Because of the dome-shaped character of the uplift, the tendency has been to locate the main watershed of the region at its apex, with a radial arrangement of the main streams with respect to it. Moreover, since the sides of the dome have a slightly greater slope than the graded slope of the streams, the valleys are cut to greater depth in the heart of the region than on its flanks. The vertical distance between the old and new base levels is greatest there.

When we pass to the Paleozoic rocks which everywhere surround the region, dipping slightly away from it, the stream adjustments necessarily differ, owing to the different character and arrangements of the rocks, which lie with their exposed edges parallel to the border of the region. The original radial streams flowed across these beds, but the tributaries which developed to these radial streams flowed along them and would develop mainly on the softer belts. With successive uplifts of the region, these adjusted streams would be more advantageously situated than many of the radial streams, and would increase in size at their expense, converting them into tributaries. This process has had much to do with the production, on all sides of the region of main drainage valleys parallel with its sides, though by no means the only factor involved.

Glacial history

This long erosion period was terminated by the great change in conditions which ushered in the Glacial period. The long and complicated history of the region during Glacial times is but imperfectly known. It was well within the field of action of the

great Labrador ice sheet for a long time. From analogy with other regions it may be inferred that there was more than one advance and retreat of ice sheets over the district, but how many and how extensive are purely conjectural matters for the immediate region. The last ice advance destroyed, for the most part, the traces of the presence of its predecessors.

Coming down on the region from the north and northeast, the Labrador ice sheet had its advance opposed by the elevated mass of the Adirondacks and was forced aside by it into two great ice streams which worked their way around the region. The one advanced up the St Lawrence valley and turned south along the west side of the Adirondacks, and thus reached and entered the Mohawk valley from the west; the other moved south through the Champlain valley, reaching the Mohawk at the east end. As the ice increased in thickness, it encroached more and more on the flanks of the region till finally it overswept the whole, and persisted in this condition for a long time. While the basal currents of the ice continued to be controlled by the topography, the main mass swept over the region in a general southwesterly direction. Ultimately changing conditions brought about recession. The thickness was least over the highlands, and the ice would first disappear there, leaving the two great currents sweeping round the region, as they did during the advance. These slowly dwindled and disappeared northerly.

The final disappearance of the ice left the topography modified both by glacial wear and glacial deposit, but with its larger features little changed. Ridge slopes were smoothed, summits rounded, valleys clogged with deposit, lakes produced either by inequality of deposit or by local excessive downward erosion, stream courses more or less modified, a host of minor changes much altering the appearance of the region.

Postglacial history

During the continuance of glaciation changes in altitude took place, and at the time of final melting away of the ice from the St Lawrence valley the elevation was much less than at the beginning of glaciation, was in fact sufficiently low to enable the

sea to run up the valley into Lake Ontario and to invade the Champlain valley also, producing a huge, branching estuary. In these waters marine sands and clays were deposited, and, though unconsolidated, these still remain in considerable bulk, their marine origin distinctly shown by the marine fossils which they contain.

Gradual elevation of the region since, greatest at the northeast, and amounting to about 600 feet at the lower end of Lake Champlain, has brought the region above sea level and shrunk the St Lawrence estuary to its modern proportions. This upward movement is probably still in progress.

But a few thousand years have passed since the ice disappeared. Erosion has made but little progress in obliterating its traces except along the immediate stream valleys. Since the streams have been more or less shifted from their preglacial courses, they have been obliged to recarve their valleys in whole or in part, and they are actively at work at this task. The steady rise of the land in postglacial times has given them a steadily lowering base level, and, though they have cleared away much of the glacial deposit from their paths, the amount of rock cutting done is not great.

THE ROCKS

Precambric rocks

While in many parts of the Adirondacks areas of varying size are found in which the rocks that occur may be unhesitatingly classed as Grenville sediments or as later igneous intrusions, over much of the district this is not the case, but an intimate admixture of various rocks is found, in apparently hopeless confusion. Thus we find Grenville sediments elaborately interbanded with other rocks, apparently igneous, yet seemingly conformable with them as an integral part of the series. We also find rocks which are not to be distinguished in appearance or in composition from the rocks of the great intrusions, except for perhaps a more thoroughly gneissoid character, and yet so interwoven with other rocks, so far as yet known not represented in the great intrusions, that it hardly seems possible that the two can belong together. There are also considerable areas of gneisses which are quite like

the uncertain gneisses involved often with the Grenville rocks, yet without any Grenville admixture, and the relationship of such rocks forms a very difficult problem. The Grenville belts and patches and the areas occupied by the later igneous intrusions have been in the main discovered and mapped. There yet remains the exceedingly difficult problem of the separation of these mixed belts into their several elements, and the working out of their affiliations. This is likely in many cases to prove impossible, and in nearly all cases the amount of intermingling is so great as to render attempts at detailed mapping of the several elements futile, and to require their designation as belts of mixed rocks.

Grenville rocks. The most characteristic of these are the limestones. They are always thoroughly, and usually coarsely crystalline marbles, which even when purest contain scales of graphite. They vary greatly in purity and usually contain green and white pyroxenes, apatite, phlogopite, quartz and scapolite, often in large quantity. In the thick beds these are more apt to be concentrated in the outer portions, in fact the limestone often grades into a pyroxene quartz rock, with or without scapolite, or else into a nearly pure pyroxene rock. Some beds of apparently pure limestone are found to contain a large quantity of white pyroxene, and when this has altered to serpentine, as it tends to do, the white and green mottled, calcite serpentine rock known as ophicalcite results.

There is always found associated with the limestones a series of curious schists and gneisses, often found also where no limestone is present, which are difficult to describe, owing to their many phases, but which are easy of recognition and are as characteristic of the series as are the limestones. They vary from exceedingly quartzose to quite basic rocks. Garnet, graphite, sillimanite, pyrite and white pyroxene are very frequent and characteristic minerals. Many of the beds, specially those which contain pyrite, weather readily to a peculiar, rusty looking rock, seemingly much more altered than is actually the case. Many others are exceedingly quartzose, so much so as strongly to resemble quartzites, but these are found to contain usually much alkali feldspar, rocks that

contain more than 75% of quartz being uncommon. Locally recrystallization has produced very coarse grained varieties of these rocks, the quartz appearing in large sheets and bunches. But such are usually interbanded with layers in which much pyroxene is associated with the quartz.

Garnet is often a very abundant mineral in these rocks, though more abundant in the more feldspathic varieties than in those purely quartzose. Graphite is more apt to appear in the rusty-weathering gneisses. In certain beds garnet becomes the predominant mineral, but these make small bulk in the series as a whole. Sillimanite is also found mainly in the quartzose gneisses, perhaps specially in those rich in garnet. At times it is only sparingly present as microscopic inclusions in the quartz, at other times it becomes quite abundant and is in larger needles.

In the more basic gneisses pyroxene is usually the most abundant dark mineral, though biotite and phlogopite micas are also frequent, some very micaceous bands occurring. Aside from frequent narrow bands of amphibolite, hornblende is a relatively rare mineral in the Grenville rocks. These amphibolites may be sedimentary, but seem to the writer more likely to represent original igneous dikes or sheets intruded into the series. Since, however, there is considerable variation in their appearance and make-up, they may be partly of one origin and partly of the other.

These Grenville rocks have the composition of sandstone, shales and limestones and their intergradations, and have a wholly different mineralogy from any known igneous rocks, whether metamorphosed or not. Under metamorphism they seem to have wholly recrystallized and to have been greatly stretched in one direction, giving rise to the foliation, and drawing out such igneous rocks as had been intruded into them into parallel bands with a foliation in common with them. The limestones were the most plastic of the beds under metamorphism, and, where the rocks have been most compressed, have often been so squeezed as to comport themselves much like igneous rocks, pressing into fractures in, and inclosing a number of fragments of, the more brittle inclosing rocks, producing combinations which have a strong external

resemblance to conglomerates. To a minor degree the same sort of thing is shown in the gneisses, two adjacent bands of different brittleness showing the more brittle ruptured and the other squeezed into the break. This has often happened to the basic bands in the acid gneisses for example. On a yet smaller scale it is often shown among the various minerals of a single rock.

Along the eastern border of Franklin county, extending northward for a few miles from Franklin Falls, are considerable masses of a coarse, rusty brown rock which consists of little else than quartz and microperthite feldspar. The quartz is in flattened lenses or spindles up to an inch or two in length, all with the same orientation, and surrounded by a mosaic of microperthite. The belt adjoins a belt of Grenville rocks which includes limestones; and Kemp interprets the rock as a recrystallized and squeezed conglomerate.[1] While this view may be the correct one, it is desired to call attention to the fact that the belt is also in close association with a mass of augite-syenite belonging to the later eruptive series, that much of this rock possesses the same spindle quartz, and that much of it consists of little else than feldspar and quartz. The resemblance is so close that the writer's disposition has been to refer the rock to these syenites, as a somewhat aberrant member, and this alternative view is thought worthy of record.

In nearly all exposures of the Grenville rocks there is found an admixture of red, gray and black gneisses which have the composition of igneous rocks, granites, syenites, diorites and gabbros and are thought to be such in a much metamorphosed condition, though for the most part they have lost all trace of the structures and textures of such rocks and possess an evenly granular texture, due to thorough crushing or granulation of their minerals, accompanied by a certain amount of recrystallization. They now form red, orthoclase gneisses, amphibolites, and gray to black, granular gabbroic gneisses. They are usually so involved and interbanded with the sedimentaries as to appear

[1] Am. Ass'n Adv. Sci. Proc. 49:169.

bedded and like an integral part of the series. But their composition and character seem to point to the igneous origin of a large part, if not the whole, and they likely represent dikes, sheets and small intrusive masses, somewhat later than the sediments.

All these rocks are often cut by rusty looking amphibolite dikes which cut across the foliation, and represent somewhat later intrusions, likely of diabase, but so old and profoundly altered as to present little resemblance to the original rock except in composition.

These gneisses are further cut by yet later granites and gabbros, rocks which have not been so profoundly metamorphosed, but which still retain sufficient traces of their original structures as to render their origin certain. The finding of these is quite what should be expected, since all younger igneous rocks must have cut their way through these gneisses in working their way toward the surface.

At the present day the Grenville rocks are found in numerous long, narrow belts around the borders of the Adirondacks, but mostly only in small, disconnected patches in the heart of the region. The reasons for this will appear later, but in a word it seems due in large measure to the greater amount of erosion which the Precambric rocks have undergone in the latter situation. The belts are larger and more numerous on the south and west sides, and are infrequent on the north, except at the extreme northwest. Kemp has emphasized the greater abundance of limestone in the belts on the west and the greater quantity of quartzose gneisses on the east. In the large way this is the case, though both rocks are found in each locality. Both are also found in the scattered patches which extend through the heart of the region.

The base and summit of the Grenville are both unknown, and the thickness of the series is therefore purely a matter of guesswork. The rocks were deposited all over the region, but erosion has removed all but the present belts and patches. The lack of

summit to the series is therefore what would naturally be expected, and it may be legitimately argued that the thickness must have been very great, since so great an amount of rock has been worn away. It is by no means meant to imply that these rocks formed the whole mass of what has been removed, but it is thought that they must have constituted a respectable percentage of it. Even the remaining fragments indicate a very considerable thickness for the formation.

The nondiscovery of the base is not so easily accounted for. It is a water-deposited formation and must have been laid down on some floor, and it would naturally be expected that some evidence of what this floor was would be forthcoming. But the great metamorphism which has destroyed the old rock structures and given them a common foliation, the inextricable intermingling of igneous rocks with the Grenville sediments, and the later great igneous invasions from beneath have so disguised the rock relationships as to make it very likely that the base of the Grenville will never be satisfactorily made out in the region.

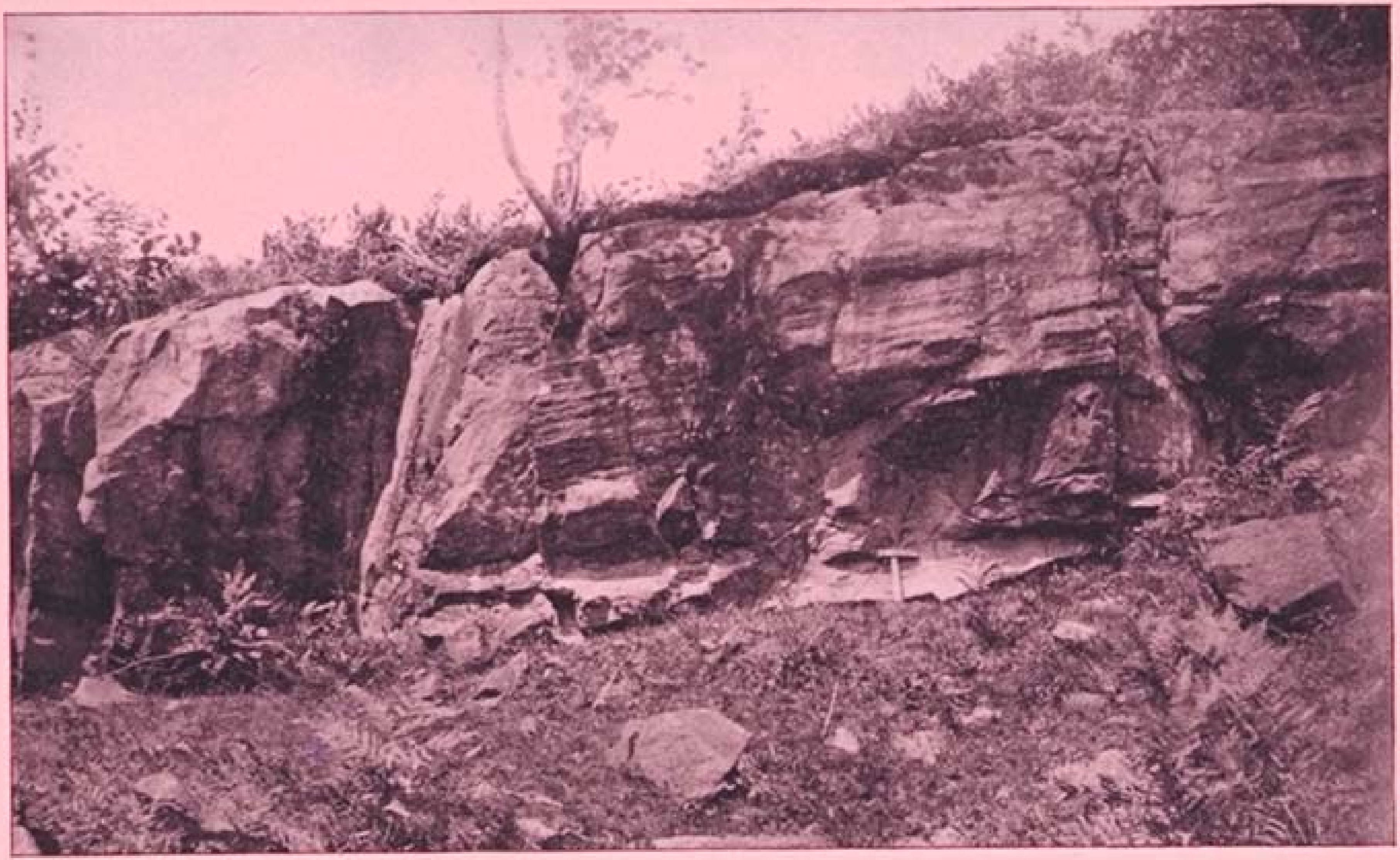
Doubtful gneisses ("Saranac" formation). In the portions of the Adirondack region with which the writer is familiar the only large body of gneiss which is practically free from all Grenville admixture and at the same time seems to have no connection with the later igneous intrusions, is found in a belt running through northern Clinton and Franklin counties, adjoining the Potsdam boundary. It is not utterly free from Grenville rocks, since a few small patches of these do occur, though unfortunately exposures which disclose the relations between the two nowhere appear. The presence of these few small patches in the great body of gneiss furnishes one of the main arguments for the distinction between the two, since it is unlikely that the distinctive Grenville rocks would be present in such slight quantity were the gneisses affiliated with them, that is, were either sediments or were igneous rocks of Grenville age.

These gneisses are prevailingly red, acid gneisses whose usual feldspar is orthoclase (or microperthite or microcline), and which

have the composition of granites. They vary much in coarseness from place to place and from band to band, ranging from finely and evenly granular varieties (which are the prevailing ones) to those which are quite coarsely crystalline. An alkali feldspar (microperthite, microcline or orthoclase in order of abundance) and quartz are the prevailing minerals, magnetite is always present, and usually hornblende in small amount as well. Biotite sometimes occurs instead of hornblende or together with it. The coarser gneisses often show traces of cataclastic structure, larger individuals, usually of feldspar, being surrounded by a granular mosaic which seems to have resulted, at least in part, from the crushing of the larger individuals. The fine grained varieties have the character of this mosaic throughout, the larger individuals being absent, so that, though they are likely akin to the coarser rocks, being simply more thoroughly granulated representatives, due perhaps to original finer grain, it is impossible to be certain that this is the case.

Along with these red gneisses, often interbanded with them with seeming regularity, often found in large masses, are two other kinds of gneiss of common occurrence. Like the red gneiss, they show many variations in composition and appearance, and also show a rude foliation, usually parallel to the banding. The more abundant sort is usually gray in color and consists essentially of pyroxene and feldspar, both plagioclase and orthoclase. The pyroxene may be either augite or hypersthene (or enstatite), or both, augite being the more frequent. The usual augite is a deep emerald green and shows pleochroism from green to yellow green, resembling aegirine augite. Magnetite is always present and sometimes a little hornblende and biotite as well. Either orthoclase or plagioclase may be in excess and either may be present to the exclusion of the other. The plagioclase is usually oligoclase but sometimes andesin. These rocks usually show an evenly granulated or granulitic structure quite like that of the fine grained red gneisses, but how much this is due to granulation, or to recrystallization, or may even be original, can not be determined.

Plate 1



Contact of gneiss and granite near Duane

The other gneisses are black and consist essentially of feldspar and hornblende, with or without pyroxene, in other words, they are amphibolites. They have often a massive appearance and are in general more abundant where the gray gneisses are scarce or absent. The feldspar may be plagioclase or orthoclase or both, but the former much predominates, and is usually andesin or oligoclase. Pyroxene seldom equals the hornblende in quantity and is often absent. The rocks seldom show any traces of crushing but seem to have largely recrystallized.

These rocks often occur in thick bands or masses, often in thinner masses interbanded with red gneiss, and very similar rocks are often found in thin bands or bunches in the red gneiss. The latter may be either segregations or inclusions, it being usually impossible to determine which. Very similar rocks are also found as dikes cutting the red gneiss. These usually have a more rusty appearance than the ordinary rock and may be either offshoots from it or may represent a different and later rock.

These amphibolites are often found involved with red, granitic gneisses which cut them intrusively, both cutting across the foliation and sending a multitude of thin sheets into the amphibolite along the foliation planes, producing a red and black gneiss [pl. 1]. In such case the amphibolite is clearly the older, but in all such the question arises whether the granite is merely a phase of the ordinary red gneiss, or whether it is a different and younger rock. Since in nearly all cases these granites are not so foliated as the red gneiss, but retain distinct traces of igneous textures, often abundantly, it is thought that they are likely younger and not to be classed with it. Among other localities such granites are widely shown around St Regis Falls in Franklin county.

Nearly all, if not all, of these doubtful gneisses seem to have the composition of igneous rocks, though the question can not be fully decided without a large amount of chemical work. The gray gneisses are perhaps the most questionable in this respect. There

is a range in composition from granites through syenites and diorites to gabbros, all intermediate gradations appearing. If there be any rocks exposed in the region which are older than the Grenville rocks, they are found here. Unmixed with Grenville rocks, they extend along the Potsdam boundary on the north side of the Adirondacks for a distance of 70 miles. Nowhere else in the region is a belt of such length known, though there may prove to be one of even greater dimensions in the little studied southwestern area. Smyth has shown that a great, unbroken extent of gneisses occurs there, but these may prove in large part to belong with the later intrusions. Grenville gneisses may be also found more abundantly than yet appears, when the region is covered in more detail. Such gneisses are abundant north from Little Falls, though no limestones occur.

These gneisses present just such an igneous complex as is found in all parts of the earth's surface where these very old rocks are exposed, which are thought by many to represent the original cooled crust of the earth, or rather its downward extension. There is much to be said in favor of this view, though it can by no means be held to be fully established. The main difficulty of its adoption so far as these special rocks are concerned is that very similar, or identical, gneisses are found either interbanded with the Grenville rocks or else cutting them intrusively, as has already been noted. If the two are not identical, it should be possible to demonstrate differences between them, and the future may show this possibility. If they are identical, the only possible way in which they could represent the floor on which the Grenville rocks were laid down would be to hold that in many places, after the deposition of the Grenville rocks, these underlying rocks had been rendered plastic by heat and compression and had thus comported themselves as igneous rocks. The difficulties against this view are great, and the whole question is a most perplexing one.

To the northward in Canada there are great stretches of country occupied by similar rocks, and the name "Ottawa gneiss" is there given to the formation. Uncertainty as to the equivalency of the

two led the writer, some years since, to propose the name "Dannemora formation," from Dannemora mountain in Clinton county for these gneisses of the northern Adirondacks, the name to serve unless equivalency with the Ottawa gneiss can be shown, in which case that name should be adopted. Since, however, possible confusion with a noted Scandinavian locality may result, the name Saranac formation is suggested to replace it. The rocks are well exposed along the river of that name, in Clinton county, and in its near vicinity.

Anorthosite. This was the first of the somewhat later, great igneous intrusions which invaded the rocks already described from below, breaking them up, pushing them aside or raising them on its back, and inclosing great horses of them in many places. The fact that it has not been so excessively metamorphosed as the previous rocks is indicative that it is considerably younger than they, as is the further fact that its character indicates that it solidified at considerable depth, and that therefore the Grenville sediments must have become buried under a considerable thickness of later deposits, since worn away, before the intrusion took place.

The Adirondack anorthosite is found principally in one great connected mass, seemingly one single intrusion, though this may not be the case, occupying a great area in Essex and southern Franklin counties, of rudely triangular shape with indented base and blunted apex, the base at the north. The base is some 55 miles across, and the hight of the triangle some 40 miles, the area of country involved being some 1200 square miles at a rude approximation. Occasional small areas of other rocks, in part Grenville or doubtful gneisses, in part later intrusives, are found within it, but, mostly, it extends unbroken throughout. The inclusions, or horses, of various gneisses are most numerous near the borders of the mass, and some great tongues of the outlying rocks project into it. There are also a few outlying masses, mostly of very small size, the Rand hill mass in Clinton county, which has an area of some 4 square miles, being perhaps as large as any. These may represent independent smaller intrusions, but

more likely are simply outliers of the main mass, connected with it not far underground. The present areal distribution of the rock merely gives its extent in the plane in which the present erosion surface cuts it. Since this surface is irregular, we have some slight idea of the thickness of the mass, the higher mountain peaks furnishing vertical sections of over 3000 feet. But the amount which has already been removed by erosion can be but vaguely estimated, and the extent of the mass in depth is wholly problematic. Any estimates of the original bulk of the mass can be nothing but pure conjectures, except that it can safely be said that it was vast.

Mineralogy. These rocks are composed mainly, and sometimes wholly, of basic plagioclase feldspar, usually labradorite but sometimes bytownite or anorthite. They are eruptives of the gabbro family extra rich in feldspar, which forms from 90% to 100% of the whole rock throughout most of its extent. The minerals next in abundance are augite and ilmenite (or titaniferous magnetite), followed by hypersthene. Minute apatites are usually present. In the many differing phases which the rock presents, several other minerals creep in, the more common of which are hornblende, biotite, garnet, microperthite, quartz, oligoclase and a sulfuret, either pyrite, chalcopyrite or pyrrhotite. These are the original minerals of the rock except where they are due to recrystallization consequent on metamorphism. Subsequent alteration has locally produced other minerals, notably zoisite, epidote, chlorite, scapolite and muscovite, and surface decay has formed yet others.

The feldspar is usually labradorite, twinning striations showing plainly on fresh cleavage surfaces. The thin section usually shows it to be full of minute, rodlike inclusions, all with parallel arrangement, of some opaque mineral, likely ilmenite. (These are likely responsible for the usual dark blue color of the mineral, and probably for the occasional iridescence, in greenish blue colors, as well. This is by no means so frequent or so well displayed as in the Labrador and Norway anorthosites, but is a common phenomenon in the region.)

Labradorite

The other minerals call for no special comment. An augite which is light green in thin section, is next in abundance to the feldspar. Orthorhombic pyroxene is in general not so prominent. It is usually hypersthene but sometimes bronzite. Ilmenite always occurs with these, but in the normal anorthosite all these are in small quantity, constituting ordinarily less than 5% of the rock.

Texture. The original anorthosite must have been extremely coarsely crystalline, and likely coarsely porphyritic. Under metamorphism the rock has been granulated in varying degree, here but little, leaving the rock still very coarsely crystalline, there excessively, producing a finely granular rock, all intermediate gradations between the two being found. In the coarser rocks the large feldspars are often from 2 to 5 inches in length and are universally dark colored, often showing straining and bending as a result of metamorphism. The granular feldspar is lighter colored and in thin section does not show the opaque rods which characterize the other. It has plainly originated from the crushing, in whole or part, of the large feldspars, crushing under such great load of overlying materials as to cause the rock to remain firm and resistant during the entire process; in fact, the granulated rock is often stronger than the other.[1]

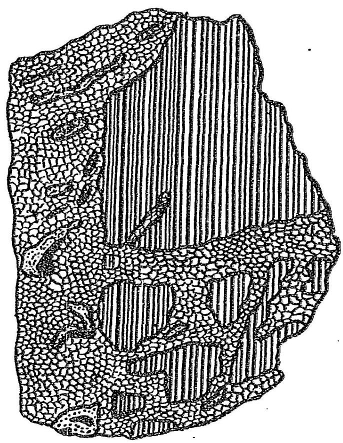


Fig. 1 Drawing of a portion of a hand specimen of anorthosite gabbro from near Keeseville, showing a large labradorite crystal which has been broken into several pieces, these being forced apart and granulated around their edges and the gaps filled by granulated material, the rock remaining firm and tough throughout. The black mineral is ilmenite, and the dotted is granular garnet. The uniform cleavage and twinning of the fragments of the large crystal demonstrate their identity.

Differentiation. As the borders of the anorthosite are approached, the rock invariably shows some variation in character,

[1] For detailed descriptions of these textures, *see* Adams, F. D. Geol. Sur. Can. An. Rep't. v.8. pt J. p.103–15.

the usual one being that the pyroxenes and ilmenite increase in amount and come to constitute from 15% to 35% of the rock, which thus tends to approach gabbro in character. It is, however, much too feldspathic for normal gabbro and may well be called anorthosite gabbro, since it represents a distinct intermediate stage. With this mineralogic change there is always found an accompanying change in texture, the rock becoming always less coarsely crystalline, the big feldspars diminishing in both number and size and the amount of granular mosaic increasing. The rock also becomes more gneissoid. In this phase garnet is sure to creep in, often in considerable quantity. It develops in the main at the contacts between ilmenite and feldspar, the one furnishing the iron, and the other the lime, alumina and silica which enter into its formation. Garnets may form in this way, either during the original cooling of the rock or owing to subsequent metamorphism, and it is usually impossible to say, in these anorthosites, whether they are to be referred to the one or the other, or to both methods of formation.

It is not meant to imply that changes of this sort occur only as the edge of the mass is neared, but rather to point out that they do uniformly occur under those conditions. But the same rock is often produced well within the anorthosite mass by local differentiation. It is in fact but a more extreme differentiation of the same sort that gives rise to the local development of great masses of titaniferous magnetite such as occur about Lake Sanford in Essex county and have been described in detail by Kemp.[1]

This anorthosite gabbro forms the greater part of the boundary of the Franklin county portion of the anorthosite mass. But on the south a yet greater change takes place, and the anorthosite gabbro passes over into a dark colored gabbro gneiss. This rock has not yet been seen in fresh condition, and hence has not received the thorough investigation that its interest and importance demand. The change is of the same sort as that involved in the passage of anorthosite into anorthosite gabbro, but is more ex-

[1] U. S. Geol. Sur. 19th An. Rep't, pt 3, p.383–422.

treme. As has been seen, that consists (1) in a change in composition due to increasing amount of pyroxenes and ilmenite with corresponding diminution of feldspar and the appearance of garnet in quantity; (2) in a change in texture, the rock becoming less coarsely crystalline and the large feldspars diminishing in frequency and size, with increase in the amount of granulated material; and (3) in the rock becoming more prominently foliated with concentration of the dark minerals along the cleavage planes. In this further change the dark minerals come to form 50% or more of the rock; the large feldspars become constantly smaller and less frequent up to complete disappearance; and the rock becomes eventually a finely granular, well foliated, dark gneiss. The change from the anorthosite into this rock is gradual, and the relationship unmistakable; yet to an observer first coming on the rock from without the anorthosite area, such a relationship would seem most improbable. This gneiss is just as clearly a border differentiation product of the anorthosite gabbro as that is of the anorthosite, a differentiation produced in the molten mass after it had reached its present resting place and while cooling. It is however impossible to say why this further differentiation has taken place only on this one side of the mass instead of rather uniformly about the whole, as is the case with the anorthosite gabbro.

Surrounding rocks. The Franklin county anorthosite is bordered by all sorts of rocks, both Grenville and doubtful gneisses and later igneous rocks. That it is younger than the Grenville and some of the doubtful gneisses is definitely established by (1) the fact that masses of varying size are found inclosed in the anorthosite; (2) by the fact that the few contacts exposed show the anorthosite cutting them and sending tongues into them; and (3) by the fact that, where no contacts are exposed, the anorthosite can be shown to cut out the other rocks along their strike. The later date of certain igneous rocks, shortly to be described, is mainly deduced from the finding of dikes of what are thought to be identical rocks which cut the anorthosite. So far as the actual dikes are concerned, there can be no question of their later

date; the uncertainty connected with the matter arises from the fact that in no case has it so far been possible to trace these dikes to any connection with the near-by larger masses, of which they are thought to represent offshoots, so that the correlation between the two depends merely on rock similarity. At the one or two exposed contacts it seems quite certain that the anorthosite is the older rock, but here again there is some question as to the actual identity of the rock which cuts it.

At two localities near the anorthosite boundary, border rocks have been discovered which, instead of exhibiting the ordinary change to anorthosite gabbro, disclose a gradation toward syenite. Such have only been noted in localities where the anorthosite is bordered by a syenite which is thought to be younger, and the rock represents a transition stage between the two, though much closer to anorthosite than to syenite. The precise significance of these rocks is not known, the field exposures not being sufficient to give any idea of the relationships to the two rocks, and, since the presence of an intermediate rock of this sort can be accounted for in several ways, and gives no evidence as to the relative age of the other rocks, speculation on the subject is of no value, in the lack of corroborative field evidence.

Anorthosite outliers. In the northern Adirondacks there are two considerable anorthosite outliers in Clinton county and two very small ones in Franklin county. Not unlikely other small ones will be discovered when the region is mapped in detail, work of this sort on the Long Lake sheet of the new topographic maps during the past season having first brought to light the two Franklin county outliers mentioned above. Kemp has mapped several on the south in Essex and Warren counties.

The two Clinton county outliers are those at Keeseville and Rand hill. The former is not strictly an outlier but rather a tonguelike offshoot from the main mass, the connection being bared by erosion. As in all the outliers, the rock here exhibits the characters of the border portions of the main mass rather than of its center, in other words is anorthosite gabbro, not so coarse grained as, but more gneissoid than the usual rock, with from

10% to 25% of minerals other than feldspar. Much of it is very gneissoid and finely granular, with great development of garnet. Elsewhere it becomes tolerably coarse with frequent, often very large feldspars remaining. It varies very rapidly in character from place to place, so that practically all varieties of the rock may be collected within a small area. This, together with the accessibility of the locality and the frequent exposures, make it a magnificent collecting ground.

The Rand hill rock departs somewhat from the ordinary type and is a most interesting rock. It is mostly thoroughly gneissoid and with no feldspar augen, these only appearing in quantity at the northern edge of the exposures. Since this is the more likely condition of the central part of the mass, and since further exposures in this direction are cut off by the overlying Potsdam sandstone, it is probable that the rock extends considerably farther northward under the Potsdam covering.

The most important difference between this rock and the usual anorthosite gabbro consists in the constant presence of quartz in considerable amount, forming from 5% to 10% of the rock. Another difference is found in the comparatively large amount of apatite present, the average of the rock holding from 3% to 5% of this mineral and the amount not infrequently rising to 10%. Aside from these the minerals are those of the usual anorthosite gabbro, though the minerals other than labradorite form from 30% to 35% of the rock.

The primary minerals which have been noted in the rock are feldspar (usually labradorite), augite, quartz, hornblende, hypersthene, apatite, ilmenite, zircon, pyrite, pyrrhotite and titanite. Secondary minerals are garnet, hornblende, biotite and quartz. There are other minerals present which have resulted from surface alteration of the foregoing, but they are the usual decomposition products formed under such circumstances. The order of crystallization was the usual one, first the zircon and apatite followed by the iron ores, then the hypersthene, augite and hornblende, then the feldspar and finally the quartz. The periods of formation of the pyroxenes and feldspar largely overlap. Augite is

much more abundant than hypersthene. There is great variation in the relative amounts of augite and primary hornblende, and sometimes the latter preponderates.[1]

The two outliers in Franklin county are very small, each only a few square rods in extent. The one is about 6, the other some 8 miles distant from the edge of the main mass. Considering their small size, they are rather surprisingly coarse, that is, on the hypothesis that they were intruded into the surrounding rocks, yet much of the rock is very gneissoid. In the one case the surrounding rocks are thought to be later eruptives, the observed contacts seeming to bear out that view, so that the anorthosite is in the nature of a huge inclusion in these eruptives. But there are some difficulties in the way of this interpretation, and, till the material is more thoroughly studied, it can not be positively stated that it is the true one.

About the other outlier there are no exposed contacts with the surrounding rocks, which are gneisses of uncertain nature and origin, and the relations between the two are wholly uncertain.

At Rand hill magnificent contacts of the anorthosite gabbro with gneisses thought to belong to the Dannemora formation, are shown and definitely prove the anorthosite to be the younger rock.

Whiteface type of anorthosite. This name has been proposed by Professor Kemp for a peculiar type of rock, rather uncommon in the Adirondack region, which reaches a considerable development on, and in the vicinity of, Mt Whiteface. The main mass of the rock is in Essex county, but it gets over the border into Franklin at Franklin Falls, and into Clinton county on Wilmington and Catamount mountains. In both of these situations it becomes much involved with other rocks, and about Franklin Falls it often appears so interbanded with Grenville rocks as to seem like an integral part of the series.

The rock has the mineralogy of anorthosite, or rather of anorthosite gabbro, though quite a different-looking rock from the ordinary types. It is mostly quite thoroughly gneissoid and characterized by the color of the feldspar, which is milky white, even when perfectly fresh and unaltered. In the writer's exper-

[1] For a more detailed description of this rock, *see* 19th An. Rep't N. Y. State Geol. p.r52–r59.

ience with the ordinary Adirondack anorthosites, white feldspar is rare and where occurring is due to local alteration, which is distinctly not the case in these "Whiteface" rocks. These are also much richer in hornblende and pyroxene than the ordinary anorthosites, though nearly pure feldspathic types have some small local development, as for example near the bridge at Franklin Falls. They differ also in the prevailing very gneissoid character, but occasional feldspar augen do occur and sometimes reach considerable number and size. A single hand specimen of the feldspathic rock from Franklin Falls which lies before me, shows three such augen which are more than an inch in length, besides several smaller ones. The structure is plainly cataclastic in these less gneissoid types.

The slides from the Clinton and Franklin county rocks show a general predominance of hornblende over pyroxene, though both occur in considerable amount. The pyroxene is a deep green augite, no hypersthene having been noted. The feldspar is mostly labradorite, as indicated by maximum extinctions of from 22° to 27° in the different slides. They show marked strain phenomena, such as undulatory extinction, bent twinning lamellae, and wedge-shaped or pinched out twinning lamellae. There is always some untwinned feldspar present, which is however thought to be labradorite. The accompanying minerals are the same as in the usual anorthosite, iron ores, zircon, apatite, titanite, garnet, and sometimes a little quartz, usually as a by-product of the garnet formation. The mineralogy of the rock, the local cataclastic structure, and the fact that it occurs in a considerable mass, surrounded on all sides by other rocks, seem to point to its igneous nature. The apparent interbanding with Grenville rocks at the edge of the mass gives that portion a sedimentary look, but all the other igneous rocks of the district show similar phenomena at their borders, and it would seem that the clues to the origin of these rocks must be sought in the least changed, most massive portions, rather than in their peripheral phases where metamorphism has been most excessive. The rock is therefore regarded as igneous and as belonging to the later intrusives. Its localized distribution would seem to indicate that it represents a separate intrusion rather

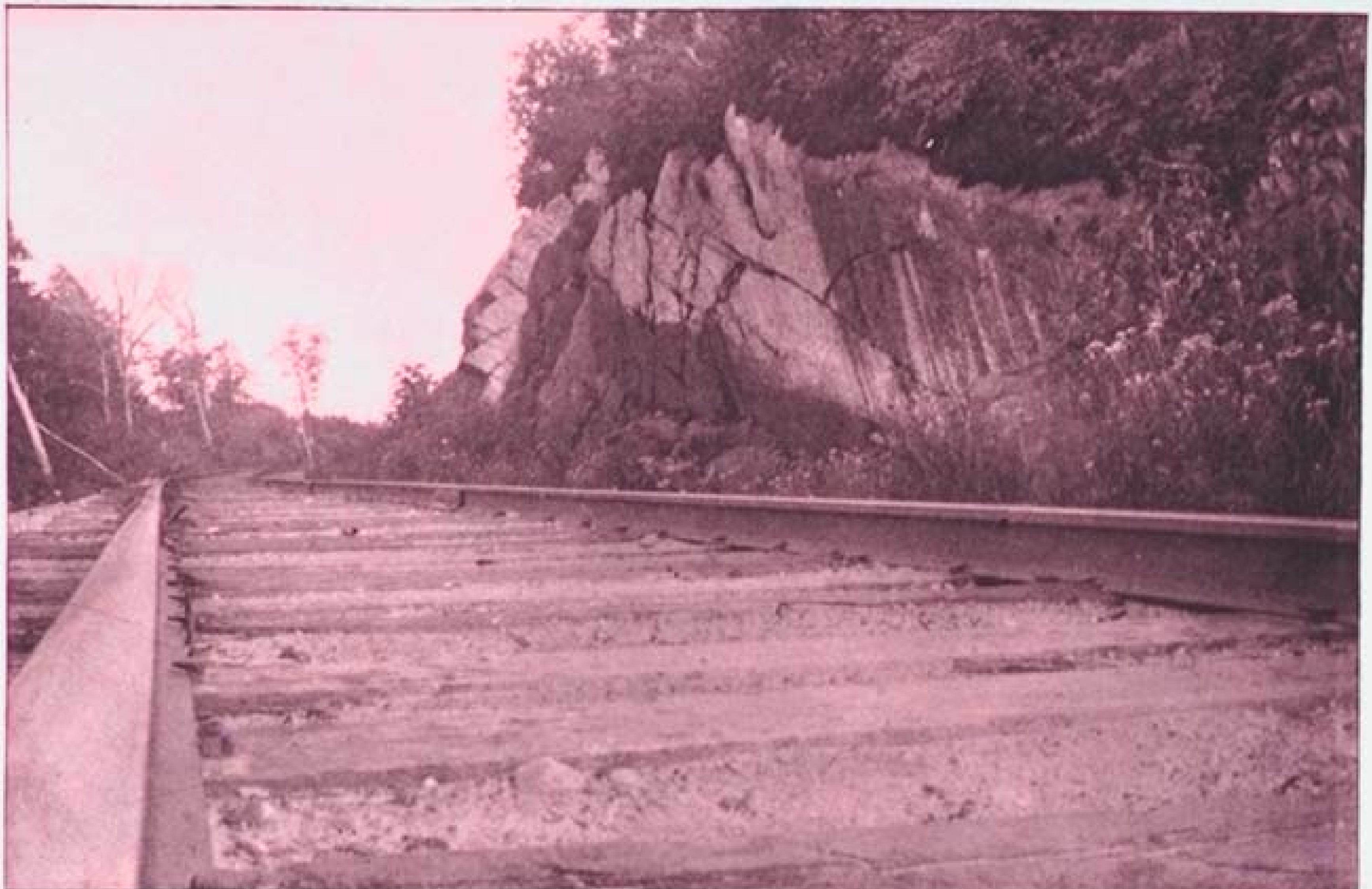
than a local peculiar phase of the general anorthosite mass, but, so far as the writer is aware, no definite evidence has been forthcoming concerning the time relations of the two rocks.

The syenites. In many parts of the Adirondack region there are found considerable areas of igneous rocks of greenish gray color and fairly uniform character, which have considerable resemblance to some phases of the anorthosite and were till comparatively recently confounded with them. In their normal phases they are readily recognized, but they show variation both in composition and in degree of foliation, giving rise to varieties from one or both of these causes which are difficult of recognition. Originally they possessed nothing like the coarsely crystalline character of the anorthosites and hence, even where least metamorphosed, the amount of granulated material is very large, and the uncrushed feldspar remnants are infrequent and of small size. Like the anorthosite, they become finer grained and more gneissoid near their borders, passing over into granular gneisses; and these become intricately involved with the bordering rocks, the whole forming a tangled complex which is exceedingly difficult to unravel.

Though grayish green on freshly fractured surfaces, these rocks undergo rapid color changes on exposure, so that the normal color is only to be seen in recent rock cuts. On slight exposure it changes to a more pronounced green, then passes over to a yellowish or brownish green, and longer exposure changes the whole mass to a rusty brown [pl. 2]. Even freshly stripped, glaciated surfaces show the latter color, though in them it is often only skin deep. In the majority of exposures only the rusty brown rock can be collected, though residual green spots may often be noted. The cause of the color changes is not manifest, thin sections of specimens of all the varieties except the rusty brown showing all the constituent minerals in perfectly fresh condition; and even the latter is often so fresh as to show little alteration in any of the minerals except the hypersthene.

These rocks are predominantly feldspathic though not so markedly so as are the anorthosites. Because of their original finer grain, they are mostly quite gneissoid, and feldspar augen

Plate 2



Railroad cut in augite-syenite ½ mile south of Loon Lake depot. The dark portion is fresh and of green color; the lighter portion is somewhat weathered and is brown

are practically absent over considerable areas, and, where they do occur, are mostly few and small. Yet such rocks are repeatedly found shading locally into others with much less apparent gneissoid structure, with feldspar augen quite frequent and with definite cataclastic structure; rocks whose original igneous textures are sufficiently well preserved to show their origin beyond a doubt.

In some cases, notably at Little Falls and Middleville in Herkimer county, where outliers of these rocks occur and where the augen are bigger and more numerous than at any other known localities, the rock seems to have originally been rather coarsely porphyritic. But for most of the rock in the region this does not seem to have been true.

Mineral composition. At the type locality, Loon lake, the rock is a quartzose augite syenite, and, since this is the prevailing character over much of the region, the description of the type will serve well for a general description of the rock.

In the Loon lake rock microperthite and oligoclase feldspars, augite and hypersthene (or bronzite), hornblende, magnetite, quartz, garnet, apatite and zircon are always present, and locally biotite, titanite, pyrite and allanite appear in addition. The rock is essentially composed of microperthite, augite and hypersthene, with quartz, oligoclase and garnet always present in varying and usually slight amount.

The feldspar is mostly microperthite. A little plagioclase always appears and seems universally to be oligoclase. Most of the plagioclase present is intergrown with orthoclase in the microperthite, and the chemical analysis indicates that this must be albite. The feldspar is usually perfectly fresh and contains to some extent minute, dustlike inclusions, as well as including small zircons, apatites and titanites and occasionally small augites and quartzes also. Orthoclase is only present as a constituent of the microperthite.

Both augite and hypersthene are usually present, the former mostly predominating. Parallel growths of the two frequently occur, often of repeated fine lamellae, the contact faces being as usual. The augite is deep green in thin section, quite like the green of the hypersthene.

Garnet occurs only sporadically and then always corrosion zone fashion, between the magnetite and feldspar. But little hornblende is found in the Loon lake rock.

In the type rock quartz occurs only sparingly, though quite quartzose varieties occur in the immediate vicinity. It is mainly in rather coarse, elongated spindles or lenses. It is also found as small inclusions in the feldspar, sometimes rather numerously and with a tendency to the production of micrographic growths.

The rock has a cataclastic structure, ranging from rather coarse varieties to those which are thoroughly gneissoid, and the granulation pretty complete. In other words, it shows the same variations in texture which the anorthosites exhibit, except for the lack of the very coarse varieties.[1]

Variability of the syenite. While this description will answer for the usual rock in many places, it shows great variability. On the one hand, the amount of quartz varies widely, rocks which contain as much as 20% of it being not at all uncommon. Increase in quartz is commonly accompanied by decrease in the amount of pyroxene and hornblende present, and hence by disappearance of well marked foliation, it being replaced by a linear structure due to the spindle form of the quartzes and their parallel alinement. This structure is quite characteristic of some of the igneous rocks of the region. This quartzose variety is usually coarsely granular and seems to weather even more rapidly than the ordinary rock, so that it is very difficult to obtain in fresh condition, and usually only the rusty brown rock can be found. It is the great similarity of this variety, which can be traced into the normal rock through all gradations, to the brown, quartzose gneiss north of Franklin Falls which Kemp regards as a possible Grenville conglomerate and which has already been referred to, that causes the writer's hesitation in accepting that origin for the rock. It may be also added that, whereas this Franklin Falls rock is adjoined by Grenville sediments on one side, it is also adjoined by augite syenite on the other, so that areally the connection with one sort of rock is no closer than with the other.

Another common variation in the rock is brought about by changes in the relative amounts of pyroxene and hornblende. In

[1] For a more detailed description of these rocks, *see* Geol. Soc. Am. Bul. 10:177–82.

the ordinary rocks the pyroxenes much predominate, but these shade into rocks in which the reverse is true, the hornblende increasing up to complete exclusion of the pyroxenes. With this increase in hornblende biotite always appears in the rock, this mineral being usually lacking in the pyroxenic varieties. Further, the more quartzose varieties are more apt to be those with predominating hornblende, though this is by no means a general rule.

Extreme variations. Besides these minor changes in character, more extreme variations of these rocks occur, on the one hand into granitic, on the other into gabbroic rocks, variations which can however be traced into the ordinary rock step by step.

The most striking instance of a change of this sort which has received careful description is found in Smyth's account of the Diana syenite belt.[1] At the time when this paper was written the syenites had not been differentiated from the anorthosites and gabbros, and the rock was described as a variety of gabbro, and its variations as variations of a gabbro mass. Smyth's description, however, shows that he clearly apprehended the differences between the rock and ordinary gabbro, and he distinctly states its syenitic character, and moreover in a later publication wholly withdraws the rock from the gabbro class.[2] Unfortunately this has not been apprehended by the several writers who have had occasion to refer to this important paper, and the special variation into a red gneiss which will be shortly described is referred to as a variation of gabbro into red gneiss. The truth is that no such variation of gabbro is known in the region, while variations of the syenite into red, granitic gneisses are the rule rather than the exception.

The special interest attaching to this Diana syenite arises from the clearly exhibited differentiation of the gray, feldspathic syenite into a dark colored rock of gabbroic appearance. The minerals are the same in both and are practically the same as in the Loon lake rock, but the pyroxene and hornblende are in much larger quantity in the dark rock, constituting from one third to one half of the whole, while they appear in but scant amount in the ordinary syenite at Diana. At the same time plagioclase increases in amount at the expense of the microperthite, and

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[1] Geol. Soc. Am. Bul. 6:271–83.

[2] N. Y. State Geol. 17th An. Rep't. p.472.

quartz diminishes, but it does not disappear, and the plagioclase remains acid, albite to oligoclase, instead of the labradorite of the gabbros. The affiliations of the rock therefore remain with the syenite, and it does not become a true gabbro. Chemical investigation brings out the same features, as will be later shown.

Of equal interest is the passage of this syenite into a red gneiss. In one direction the passage is into a finely granular red gneiss, which Smyth states to differ from the main rock only in a more complete granulation of the constituents, the formation of a little hematite, which causes the color change to red, and an increase in the amount of quartz. In another direction the transition is into a coarser red gneiss which contains a conspicuous amount of hornblende.

Besides these important evidences of great variation in the syenite mass, the Diana area is noteworthy in yet another respect. It borders a long belt of Grenville rocks for several miles; and Smyth has presented in great detail the perfectly clear evidence that it cuts the Grenville rocks intrusively, since it contains abundant inclusions of them, and since it cuts them out along the strike.[1] These relations are here shown in greater perfection than in any other locality so far described in the Adirondack region, and seem to the writer to show not only that the syenite is younger than the Grenville rocks, but also that it is considerably younger. The less severe metamorphism which it has suffered, as evinced by the considerable extent to which it retains original textures which definitely show its igneous character, when compared with the completely crushed and recrystallized condition of the Grenville sediments and associated igneous gneisses, as well as with much of the Saranac gneiss, would seem to demonstrate this clearly, and to show that, so far as age is concerned, their condition of metamorphism would require their classification with the anorthosites, rather than with the Grenville and Dannemora rocks.

Other syenite areas. So far as the Adirondack region has been studied, these syenites seem to be more abundant and important rocks in Franklin county than elsewhere, though it is possible

[1] 17th An. Rep't State Geol. p.474–81.

that future work will show that this is not the case. There are several considerable masses of the rock in this county, the chief ones being the Loon lake, Tupper lake, Saranac river, Duane and Salmon river areas. They all show very similar rocks, and all run into mixed rocks at their boundaries, that is, gneisses which seem referable to the syenite are inextricably involved with other rocks of all sorts, so much so as utterly to defy mapping except on an unwarrantably large scale. The Saranac river mass gets over the border into Essex county, and there are some small masses of the rock in Clinton county, notably in Black Brook township. Kemp has noted the presence of much similar rock in Essex, Warren and Washington counties, though here usually very gneissoid and so much involved with other rocks as to render it somewhat uncertain whether it is of the same age as the Franklin rocks or not. Undoubtedly much of the rock will be found in Hamilton and Herkimer counties when these shall have been more carefully investigated. The work of both Kemp and Smyth in these counties indicates the presence of a considerable quantity of this rock, though mostly in small masses, so that the gneissoid border phases, involved with other gneisses, are the usual types found.

Special reference may be made to the Little Falls syenite in Herkimer. The coarse syenite of the Precambric outliers at Little Falls and Middleville is very similar and wholly uncontaminated with other rocks except for a few cutting dikes. They seem quite certainly parts of the same mass whose extent is concealed by the rocks of the Paleozoic cover. To the northward is a large area of a very gneissoid syenite, much involved with other gneisses mostly of Grenville age, so much so as to defy attempts to fix the relationships of the two, but forming a complex very like that around many of the belts.

A further special interest attaching to the Little Falls syenite arises from its plainly shown gradation into a gabbroic-looking rock which is very similar to the corresponding rock at Diana and represents a variation of precisely the same sort.[1]

In one of the cuts at Loon lake is an apparent inclusion of Grenville rocks in the syenite, which is by no means so decisive

[1] For details *see* N. Y. State Geol. 20th An. Rep't. p.r85–r92.

as to the age relations as are the Diana exposures, but which nevertheless presents some interesting features, as indicated by the accompanying section [fig. 2]. The augite syenite constitutes the center and south end of the section. It is more thoroughly granular and gneissoid than in the neighboring exposures. Separating the two syenite areas is a mass of banded gneiss 12 feet in thickness [pl. 3]. Above is a 2 foot layer of a white, granular rock composed of quartz and white pyroxene in the proportion of 1 to 2. This is followed by layers of black pyroxene granulite and light colored quartzose rocks, the latter consisting essentially of quartz and alkali feldspars in the proportions of 2 to 1. The structure and composition indicate the sedimentary origin, and identical gneisses are found elsewhere in intimate association with limestones. The section is cut at but a small angle with the strike, and but one of the contacts is exposed.

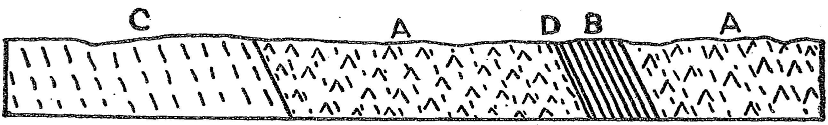


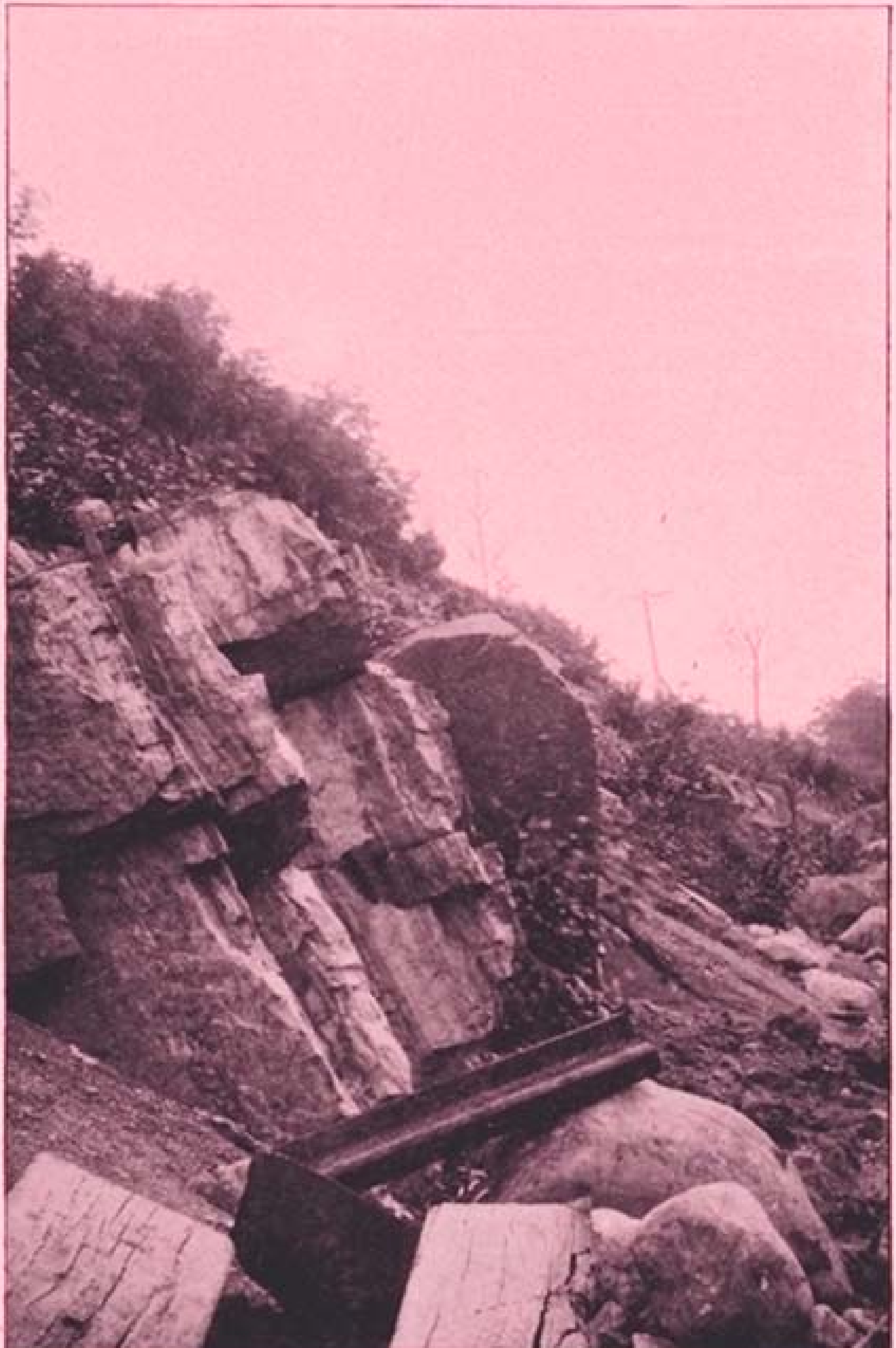
Fig. 2 Section in railroad cut near Loon lake, N. Y. *A*, augite-syenite. *B*, well banded quartzose gneisses. *C*, quartzose gneisses. *D*, biotitic sheared strip—strike north 10 degrees west. Dip of bedding and foliation 65 degrees to the west.

This is parallel to the foliation and bedding and appears like a shear zone, marked by abundant development of biotite. Beyond this middle mass of syenite fine grained, red, granitic gneisses come in, which are likely igneous but quite like rocks often closely associated with the Grenville. The contacts of this rock with the syenite are not exposed. All the rocks have a common foliation, which is also parallel to the banding of the banded gneiss.

While the field relations are not well shown, the fact that the syenite extends unbroken for some distance on all sides of the exposure, and that no Grenville rocks are elsewhere exposed, makes it evident that we are dealing with but a small mass of these rocks wholly surrounded by syenite and hence of the nature of an inclosure in it. Many examples of precisely similar nature may be cited from the areas occupied by the great intrusions.

Relations of syenite and anorthosite. Just as the Diana syenite belt, because of juxtaposition to a considerable area of the Grenville rocks, has furnished conclusive proofs of the age relations

Plate 3



Banded gneiss included in augite-syenite. The hammer is at the contact

of the two, so the evidence of age relations between syenite and anorthosite must be sought from those masses of the syenite which adjoin anorthosite. The only two such masses in the northern Adirondacks, aside from the small anorthosite outlier in Litchfield park, Franklin county, are the Tupper lake and Saranac river syenites. Each of these has furnished some evidence.

A long cut on the Saranac branch of the New York Central and Hudson River Railroad near Colby pond exposes an apparent dike of a gabbroic-looking rock some 30 feet in width, in the midst of the anorthosite gabbro of the cut. The dike shows a heavy blackish rock, darker colored and finer grained than the anorthosite gabbro. The thin section shows that its affiliations are with the syenites, and that it is quite like the gabbroic phase of the Diana syenite. It holds some 35% to 40% of minerals other than feldspar, these being augite, hypersthene, hornblende, biotite, garnet, magnetite and quartz (with small amounts of zircon, apatite, titanite and pyrite). The feldspar is entirely of intergrowth types, fine microperthitic or micrographic intergrowths of orthoclase and albite (or oligoclase). Quartz makes some 5% of the rock. The nature of the feldspar makes reference of the rock to gabbro impossible, yet it looks exceedingly like the ordinary dark gabbros of the region and is very difficult to tell from them in the field.

The west wall of the dike is well shown and is sharp, so that there seems no doubt that it actually is a dike. The igneous nature of the rock is beyond question.

Since the anorthosites grade at times at their borders into gabbroic gneisses which positively can not be distinguished from these gabbroid syenites in the field, it is evident that boundary mapping is attended with considerable hazard in districts where the two rocks adjoin and both show this differentiation.

A similar dike, 8 feet wide, is found cutting anorthosite in a railroad cut 3¼ miles west of Saranac Inn station. The main difference between the two rocks is that in this dike the feldspar, instead of consisting entirely of intergrowth types, as in the previous case, shows quite a considerable percentage of andesin, though the microperthite largely predominates. The rock is by no means so distinctly a syenite as in the previous case, but is rather an intermediate rock.

Three miles north of the depot at Tupper lake there is a small rock cut in a gabbroic-looking rock, somewhat more feldspathic than the rock of the two dikes, but very similar nevertheless and plainly closely related to them. It contains some 30% of dark minerals, and its feldspar is all of intergrowth types. Its field relations are with the syenite as a border phase, though it is close to the anorthosite boundary, and both its mineralogy and its chemical analysis show it to be a somewhat basic syenite.

In a cut a mile farther north anorthosite gabbro appears which shows rather frequent labradorite augen, but whose granular feldspars are andesin and microperthite in about equal quantity. In other words, the rock is an anorthosite with syenitic tendencies.

About halfway between Tupper Lake village and Wawbeek an interesting glaciated rock surface is shown by the roadside near the town line, exhibiting anorthosite gabbro cut intrusively by syenite, not as a single dike but as an invasion in force, wedging apart and surrounding great horses of the anorthosite. This syenite shows numerous feldspar augen and much more strongly resembles the usual syenite than do the preceding rocks. It is however more basic than the normal rock, having a considerable pyroxene-hornblende-garnet content. Feldspar forms some 75% of the rock however and is nearly all microperthite.

Nearly 1 mile farther east and hence that much farther within the anorthosite mass, is a knoll of gabbroid syenite almost precisely like the Colby pond dike. Its field relations to the surrounding anorthosite are not exhibited, though from analogy it must be a very large dike or else a small boss.

The small anorthosite outlier in Litchfield park has been already referred to. It is all surrounded by syenite gneisses and with good contacts exposed on one side. The rock is much more acid than in the previous exposures and yet is not normal syenite, though it is an igneous rock, a syenite, and identical with what appear as phases of the normal syenite elsewhere. It becomes fine grained at the contact, while the anorthosite shows no change in grain, and seems quite conclusively the younger rock; hence the disposition to regard the anorthosite as an inclusion in the other.

So far as the writer is aware, these are the only observations so far put on record in the Adirondack region which have any bearing on the relative age and relationships of the two rocks, syenite and anorthosite.[1] They definitely show (1) that the anorthosite is cut by a basic syenite, which is therefore younger; (2) that this basic syenite shows considerable variation from place to place and in one exposure bears a strong resemblance to the normal syenite; (3) that at times the normal syenite shows gradation into a gabbroid phase, best shown at Diana and Tupper lake, which is similar to the rock which cuts the anorthosite; and (4) that the anorthosite gabbro itself shows a tendency to the production of a similar rock by local differentiation, that is, a rock richer in pyroxene-hornblende-garnet content than the ordinary anorthosite gabbro, but with oligoclase andesin instead of labradorite for the feldspar and with the development of much microperthite and some quartz in addition; and that at least one dike of a like rock occurs cutting anorthosite. But it has not yet been demonstrated that the syenite found cutting the anorthosite is connected with the main masses, yet such a demonstration is necessary in order to definitely prove the younger age of the latter. It may be argued however that dikes from a syenite mass would draw their material from its peripheral portions, and, if any differentiation had previously taken place, would naturally be more basic than the main mass. The Diana case proves that such differentiation has taken place on a considerable scale; it has also taken place at Tupper lake, and it is thought that plentiful evidence of the same sort would be forthcoming elsewhere, were it not for the general unsatisfactory character of the rock outcrops which prevail in the woods. It is therefore thought that the evidence strongly points to the occurrence of a considerable body of syenite in the region which is younger than the anorthosite. The occurrence of the syenite in a great number of separate masses renders it possible however that there may be some considerable age differences between them. And the fact that in many parts of the region there occur numerous small masses of similar rocks and some larger ones too, which are thoroughly gneissoid and much

[1] For details *see* N. Y. State Geol., 20th An. Rep't. p.r25–r46.

involved with other gneisses, may indicate a greater age for these.

But the great similarity between the rocks of most of the syenite masses seems to point to a close age relationship. The gabbroid phase of the syenite would seem, like the gabbroic borders of the anorthosite, to be due to differentiation after reaching their present situations. The great similarity between the two gabbroid rocks, as well as many mineralogic resemblances between the ordinary anorthosites and syenites, would be accounted for on the supposition that both rocks arose from the differentiation of a common deep seated magma, the anorthosite being erupted first and the syenite following at a somewhat later date. Such phenomena as are presented by the syenitic phase of the anorthosite, here appearing as a local differentiation of the ordinary anorthosite, there occurring in dikes cutting it, would be explained as, the one due to differentiation in place, the other in the magma beneath, with the ascent of a slight amount of material at this stage, following closely on the heels of the main anorthosite intrusion.

Granites. Perhaps the most abundant of all rocks in the Adirondack region are gneissoid granites and granitic gneisses. These are quite certainly of various ages. The granitic gneisses associated with the Grenville rocks as well as those which make up the bulk of the Saranac formation are unquestionably much older than the anorthosite, as shown at contacts and also by their occurrence as inclusions in the anorthosite. On the other hand dikes of granite are not infrequently found cutting the anorthosite, so frequently and over such a wide territory as to argue the existence of considerable bodies of this rock whence the dikes sprang. They are if anything still more frequent in the syenite, in which small granite bosses appear as well. Also localities are not uncommon in which two different granites are found, the one cutting the other. It seems therefore likely that all the granitic rocks of the region may be separated into two great groups, an older and a younger, the former very gneissoid in character and comprising the granitic content of the Grenville and Saranac formations, and the latter much less gneissoid and affiliated in age with the later great intrusions. In the latter

certainly, and in the former probably, there are granites of more than one, perhaps of several different ages. The Grenville and Saranac rocks have been already described. It remains to consider the others. These appear in several forms, some fine and some coarse grained, some almost lacking in dark colored minerals and others comparatively rich in them, some representing well defined types which may be recognized anywhere, while others are more indefinite and variable, and all are much easier to recognize than to describe.

Granitic phase of the syenite. In several localities syenite has been noted passing into a red, granitic gneiss, as first shown by Smyth for the Diana area. In all cases observed the transition is gradual, and there can be no doubt of the unity of the two rocks. The Tupper lake syenite shows changes of the sort most excellently. The color change is gradual and intermediate rocks of mottled green and red appearance are not uncommon. Such are seen to good advantage in Litchfield park, where the numerous rock ledges, often blasted, along the carefully constructed roadways give exceptional advantages for observation. Quartz increases in amount in these rocks while pyroxene commonly disappears, being replaced by hornblende and biotite, usually in respectable amount. No analyses have yet been made of these rocks, and it may be that they do not quite reach a sufficient degree of acidity to justify their being classed as granites, but it seems that in large part they must do so, and they certainly represent as great a departure from the normal syenite type in one direction as the gabbroic variety does in the other. The rock shows the same variations in coarseness and in presence or absence of feldspar augen that the ordinary syenite exhibits. There is also in some varieties the same tendency of the quartz to assume the lens, or spindle form that is seen in the more quartzose syenites.

In going farther south this granitic phase of the syenite gives place to an even more distinctly granitic gneiss, or rather gneissoid granite, in which frequent patchy outcrops of both ordinary syenite and its granitic phase occur, and this rock extends out beyond the limits of the district which the writer has studied. The exposures have not been so situated as to permit of precise

determination of the relations between the two, and the writer is in doubt concerning them. But whether this is the same rock or a different granite, it is so like the other in appearance and in amount of metamorphism, being mostly fairly coarse and with numerous feldspar augen, that there can be little doubt of the close relationship of the two rocks, and it may be safely stated that the two, if distinct, have arisen from the same parent magma and are not far separate in time. It is simply a question whether differentiation has taken place where the rocks now lie or has taken place beneath.

Running northeast from Litchfield park are two big rock ridges, pitching northwardly with gentle slopes, but breaking down in tremendous cliffs on the southwest, which are constituted of a reddish, coarsely gneissoid rock, grading locally into green patches of unmistakable syenite, which the field relations and the thin sections show to be nothing but an extra acid phase of the syenite [pl. 17]. The rock approaches granite but is not as decisively granitic as the previous rocks. It is however another instance of the passage of the syenite into a granitic rock, and the special interest which attaches to it comes from the fact that it is surrounded on all sides by ordinary syenite and hence seems clearly a central, acid differentiation of a syenite mass.

Occasional local reddish gneisses appear in the syenite of somewhat different nature from the foregoing, and in these the color change is not accompanied by much increase in acidity. A case of the sort is met in the section at Little Falls, the rock in question being a syenite full of feldspar augen, which has locally been so mashed and stretched that the augen have become nearly or entirely crushed, the product being a granular red feldspar which has been squeezed out into flat lenses, often tailing out into the rock as thin sheets of considerable extent. In some of these a bit of uncrushed feldspar still remains, and all stages between this extra mashed condition and the ordinary rock can be observed, so that there can be no question of the origin of the granular red feldspar; the origin of the color change is not manifest however, since the augen themselves are by no means red. Furthermore, the red color is confined to this portion of the rock, and the remainder is still of the gray green of the ordinary syenite. It is

a precisely similar red gneiss that is found showing the intrusive contacts against the anorthosite outlier in Litchfield park, and which is regarded as an unquestionable phase of the syenite. The rock here however is not so mashed as at Little Falls, many augen remaining which are only partially granulated. The color change makes it an easy matter to determine just how much granular material has been produced from the crushing of each large feldspar, and the whole forms a very striking and instructive rock.

Amount of differentiation of the syenite. The field evidence, both at Diana and at Tupper lake, seems conclusive that the syenite varies into a quite basic, gabbroic-appearing rock on the one hand and into red, granitic gneisses on the other, showing thus considerably more differentiation in place than the anorthosites exhibit. The writer is also of the opinion that certain magnetite deposits of the region have originated as extra basic segregations from the syenite magma, in strict parallelism with the similar development of the titaniferous magnetite ore bodies of the anorthosite. He has however yet to meet with a case where the evidence for this is decisive, so that there is no intention here to emphasize this view unduly.

It is not yet clear whether the differentiation shown by the syenite is wholly due to changes in the rock mass itself during cooling, after the ordinary manner of such changes in igneous rocks, or whether it is in part due to the incorporation in the igneous mass of material melted away from the inclosing rocks. If the latter process ever takes place on a large scale, we might expect to find it here, in connection with these very large, and very deep seated igneous masses. The general sharp and clear-cut character of the contacts between the intrusives and the various rocks which they cut, as well as the corresponding sharpness of the contacts against the various inclusions of these rocks in the intrusives, does not seem indicative of any incorporation. Nor does the character of the border portion of the intrusive mass vary from place to place, as it successively cuts rocks of different character, as would naturally be expected on this view. Yet it is difficult to bring certain features in harmony with the other view. The usual result of differentiation is to produce a rudely radial

concentric arrangement of the different rock varieties produced, usually with the most acid rock in the center and the most basic in the peripheral portions of the mass; sometimes however the reverse arrangement occurs, the basic rock being the central one. This of course is in the large way, and insignificant local variations, such as are specially characteristic of gabbros, are not in mind. Now both at Tupper lake and at Diana the gradation into granite appears to be a one-sided one, and with no apparent sign of any tendency to concentric arrangement. At Tupper lake the gabbroic phases of the syenite, so far as they have been noted, are all in the vicinity of the anorthosite, while the gradation into granite is apparently confined to the south side of the mass, and other granites appear in force beyond. This is certainly an unusual arrangement, and the cause, though not now manifest, may perhaps be brought out by more detailed work, specially in the unexplored country to the south.

Morris granite. There is one granite in the region which presents very definite characters, is generally found only in small masses, plainly cuts all the rocks heretofore described and hence is likely the latest granite in the region, and to which for convenience of reference and because of its usual easy recognition it seems worth while to give a name. Hence the term "Morris granite" is suggested for it, because of the considerable exposures which occur cutting the augite syenite on the west slopes of Mt Morris, Franklin county.

The rock is peculiar in that it consists almost wholly of alkali feldspar (mostly microperthite) and quartz. There is a trifling amount of hornblende and magnetite usually present, and occasional minute apatites and zircons, but they seldom form more than 5% of the whole. The feldspar is red in color, usually strongly so. The rock presents both coarse and fine grained phases, and it is the former which so characteristically marks the rock. The quartz is concentrated into long spindles or pencils, or else into long flattened lenses, giving the rock a pronounced linear structure; that is, the structure appears gneissoid on fractures parallel to the spindles and not at all gneissoid on fractures at right angles to them, since here the spindles present their rounded cross sections merely. Since the quartz percentage is high, these large

spindles constitute a considerable portion of, and a very characteristic feature of the rock. Though no analyses have been made, the rock is plainly an exceedingly acid one.

The fine grained phase is however the more common one and is not so easy of recognition. It has the same mineral constitution as the coarse, but largely or entirely loses the spindle quartz character. Intermediate grades however occur. In small dikes it becomes a very finely granular, flinty appearing rock, and, where such dikes occur isolated, there may be considerable question as to their proper reference.

The fact that the two are merely phases of the same rock is shown at several localities, typically perhaps on the west shore of Big Tupper lake between Grindstone and Black bays. Here are excellent exposures which show the typical coarse granite cutting augite syenite, with the fine grained type produced as a contact phase, and constituting only a small proportion of the whole mass of the granite. Other exposures show the two in varying proportion, though as a whole the coarse type is less abundant than the fine.

This Morris granite is the only granitic rock among the later intrusives which belongs to this very acid type, and this makes it easy of recognition when it is associated with rocks belonging to this group, since it is the youngest of them all, with the possible exception of some of the gabbros. But gneissoid granites are not infrequently found in the region which cut Grenville or Saranac rocks and with none of the distinctive later intrusives in the vicinity, granites of a very acid type. When these are of the fine grained sort, as is usual, it is impossible to tell whether they are of the age of the Morris granite or are much older, older than any of the later intrusives. Such granites are quite frequent in the region, and have perhaps a specially wide distribution in the vicinity of St Regis Falls. It is quite probable that there is more than one granite of this character in the region.

Gabbros. These are mostly black, basic, heavy rocks, and have a very widespread distribution, perhaps more so than any of the later igneous rocks, but occur mostly in dikes or small masses, very seldom in masses of such size as are common with the other intrusives. The dikes are without exception fine grained black rocks. The central parts of the bosses are much coarser, the

characteristic structures of the rock being here easily made out with the eye.

These rocks show much variation from place to place, due in part to local differentiation during cooling; in part to mutual corrosive effects of adjacent minerals on each other, both during the original cooling of the rock and as a result of subsequent metamorphism; and in large part to varying severity of metamorphism. Where least metamorphosed, a simple original mineral constitution is usually shown, the rock consisting essentially of plagioclase feldspar (usually labradorite), augite and magnetite; to these hypersthene is frequently to be added, and rarely olivine. These primary feldspars and augites invariably hold a multitude of minute inclusions, the augite specially containing them in such numbers that it would often be impossible to make out the color of the mineral were it not for the fact that a narrow outer zone is usually free from them. Nor is the feldspar far behind in this respect. The inclusions in the augite are mainly opaque and consist probably of magnetite or ilmenite. In large part the feldspar inclusions consist of small augites. The structure is rather prominently ophitic in most cases, that is, the feldspar is in long, lath-shaped crystals, separated by and partially embedded in the stout augite crystals.

From the extinction angles shown by the feldspars from various occurrences, it is quite certain that they show a range in composition from andesin to anorthite, with labradorite the prevailing variety. The augite is of a pale, gray-green shade, nearly colorless in thin sections.

In addition to the foregoing, even the least metamorphosed rocks show much granular material, and rocks which consist mainly or wholly of this, with little or no preservation of the original character, are far more common than those of which the reverse is true. This granular material is, to some extent, due to corrosive interaction of the original minerals of the rock. This is most apt to take place between magnetite and feldspar but also occurs between the pyroxenes and feldspar. In general nothing of the sort takes place at pyroxene magnetite contacts. The main new minerals produced by this action are garnet and a peculiar brown hornblende, with some quartz and often biotite accompanying. These are found arranged zonally between the two

reacting minerals and may perhaps have developed during the cooling of the rock, since they are found in the least metamorphosed portions, and since such phenomena are known in other gabbros which have not been metamorphosed. In this manner are formed the well known "corrosion rims" which appear in many gabbros in all parts of the world.

In addition to these minerals there appear others in the granular condition in all rocks in which there is any trace of metamorphism. These are in the main the same as the original minerals of the rock, plagioclase (mostly labradorite), augite, hypersthene, and green hornblende. It seems quite certain that the material for the formation of these has been derived from the original minerals of the rock, and that the process has been one of granulation and recrystallization. The newly formed labradorite and augite are entirely lacking in the multitudinous inclusions which are so characteristic of the original minerals, and in virtue of which even the smallest remaining fragments of them may be detected. The original minerals may often be seen tailing off into granular material, which has evidently formed at their expense. But the grains are not mere shattered fragments of the larger crystals, but consist of a mixture of all the minerals mentioned above.

Additional minerals which are usually or occasionally present are apatite and titanite frequently, pyrite and pyrrhotite occasionally, and sometimes a little green spinel (pleonaste). Scapolite is sometimes present as an altération product, and in the gneissoid gabbros there is often considerable untwinned feldspar which may be orthoclase.[1]

Some of the more important localities in the northern Adirondacks where these rocks occur are as follows:

In Clinton county at Keeseville, where occasional dikes of the gabbro are found cutting the anorthosite gabbro, showing that they are younger; at Petersburg, where exposures of a very wide

[1] More detailed descriptions of some of these rocks may be found in the following papers:

Kemp, J. F. Am. Jour. Sci. August 1892, p.109–14.
——— Geol. Soc. Am. Bul. 5:213–24.
Smyth, C. H. jr. Am. Jour. Sci. July 1894, p.54–63.
——— Am. Jour. Sci. April 1896, p.273–81.
——— Geol. Soc. Am. Bul. 6:268–83.

dike are found on both sides of the river, showing both the ophitic and the granular types of the rock; a small boss on the northwest shore of Upper Chateaugay lake, which shows ophitic gabbro in the center passing rapidly into an amphibolite gneiss on all sides; and a considerable boss not far from the lower end of Chazy lake. These all show portions only slightly metamorphosed and still retaining ophitic structure. There are many other places in the county where wholly gneissoid rocks of gabbroic make-up occur as dikes and are in all likelihood referable to this same group. In Franklin county there is a considerable boss by the north branch of the Saranac, 2 miles east of Hunters Home, showing a fairly coarse rock with a comparatively unmetamorphosed core; there is another, well shown in cuts along the New York & Ottawa Railroad, 2 miles above St Regis Falls, which shows beautifully the gradual passage from the unchanged core into amphibolite, the latter containing a profusion of enormous garnets; and there is another showing along the west shore at the upper end of Lower Saranac lake, which is quite a large mass and correspondingly coarse, and which must cut the anorthosite, since it is surrounded by that rock on all sides, though no contacts were seen. There are here also numerous smaller masses and dikes which are more completely metamorphosed. Kemp and Smyth have shown the wide distribution of similar rocks in the eastern and western Adirondacks.

To gabbros of this type, with ophitic structure, the name "hyperite" has been applied by Tornebohm.

In many localities metamorphism has produced an amphibolite from these gabbros, instead of the merely granulitic gabbro. In these amphibolite phases there is always considerable pyroxene in addition to the hornblende, but in the field these are absolutely not to be distinguished from the amphibolites associated with the various gneisses, and these too often contain pyroxenes. Where there is an unmetamorphosed core, the origin and relations are evident, otherwise they are wholly obscure. This gradation is beautifully shown at the localities on Upper Chateaugay lake and along the New York & Ottawa Railroad referred to above.

The fact that these gabbros are found in dikes cutting the anorthosites shows conclusively that they are younger. The writer has noted gabbro dikes also cutting the syenite in the Little

Falls outlier, and hence younger. But he has so far met with no instance of gabbro cutting the syenite masses in the north, nor of cutting the distinctly later granites, though many cases are known in which granitic gneisses of uncertain age are cut. This, together with the fact that there is no evidence to show that the syenite at Little Falls is of the same age as that to the north, causes hesitation in regard to the relative ages of the syenite and gabbro there. It is thought to be highly probable however that the gabbro is the youngest rock, and that the order of appearance of the great intrusions was, first anorthosite, followed in order by syenite, granite and gabbro.

Chemical analyses. A sufficient number of chemical analyses of the rocks of the great intrusions have been made to give a very fair idea of their range in composition, and to show their close relationship to one another. To date, analyses of the later granites wholly fail so far as the writer is aware, and hence the more acid members of the group are lacking. But their mineralogy indicates a close relationship to, and gradation into the others through the medium of the acid syenites, and it may be confidently stated that their analyses will fall regularly into the series, and show a regular gradation from the acid syenites through ordinary granite to the very acid Morris granite.

	1	2	3	4	5	6	7
SiO_2	44.77	47.42	51.62	54.47	54.62	54.38	57
Al_2O_3	12.46	17.34	24.45	26.45	26.5	20.53	16.01
Fe_2O_3	4.63	4.91	1.65	1.3	.75	2.78	10.3
FeO	12.99	10.22	5.3	.66	.56	5.5	
MgO	5.34	5.21	1.21	.69	.74	1.99	1.62
CaO	10.2	8.09	9.97	10.8	9.88	5.39	6.2
Na_2O	2.47	3.48	3.49	4.37	4.5	5.2	4.35
K_2O	.95	1.89	1.27	.92	1.23	3.4	3.53
H_2O	.6	1.13	.72	.53	.91	.5	.15
CO_2	.37	......	......	......	......	......	......
TiO_2	5.26	3.6	......	......	......	.09	......
P_2O_5	.28	.06	.01	......	......	.15	......
Cl	......	.21	......	......	......	.03	......
F	......	......	......	......	......	.03	......
S	.26	......	......	......	......	......	......
MnO	.17	.06	.1	......	......	.01	......
BaO	trace	.04	......	......	......	.16	......
Total	100.75	100.01	99.79	100.19	99.7	100.03	99.16
Sp. gr.	3.09		2.798	2.72	2.7	2.7	

	8	9	10	11	12	13	14
SiO_2	59.7	61.01	60.47	63.45	65.65	66.72	68.5
Al_2O_3	19.52	15.36	16.36	18.38	16.84	16.15	14.69
Fe_2O_3	1.16		.8	.42			1.34
		10.75			4.01	3.42	
FeO	5.65		8.76	3.56			3.25
MgO	.78	.78	1.31	.35	.13	.73	.26
CaO	3.36	4.05	2.94	3.06	2.47	2.3	2.2
Na_2O	5.31	3.68	4.65	5.06	5.27	4.36	3.5
Ka_2O	4.14	3.9	4.71	5.15	5.04	5.66	5.9
H_2O	.52	.49	.09	.3	.3	.77	.4
TiO_2	......	......	......	.07	......	......	......
P_2O_5	......	......	......	......	......	......	.03
MnO	.09	.08	.12	trace	......	.07	.1
BaO	......	......	......	.13	......	......	.05
Total	100.23	100.1	100.21	99.73	99.71	100.18	100.22
Sp. gr.	2.674		2.82	2.72			

Molecular ratios

	3	4	6	8	9	11	13	14
SiO_2 ...	.8603	.9078	.9063	.995	1.0168	1.0575	1.112	1.1417
Al_2O_3 ..	.2397	.2593	.2004	.1912	.1506	.1795	.1584	.144
Fe_2O_3 ..	.0103	.0081	.0174	.0072	.0216	.0026	......	.008
FeO ...	.0736	.0092	.0764	.0785	.1014	.0494	.0475	.0451
MgO ..	.0302	.0172	.0497	.0195	.0195	.0087	.0182	.0065
CaO ...	.178	.1929	.0963	.06	.0723	.0523	.0411	.0393
Na_2O ..	.0563	.0705	.0839	.0856	.0594	.0816	.0703	.0565
K_2O ...	.0135	.0097	.0357	.0439	.0414	.0547	.0601	.0626

1 Norite, wall rock of titaniferous magnetite deposit, Lincoln pond, Elizabethtown, Essex co. Description by J. F. Kemp, analysis by W. F. Hillebrand, U. S. Geol. Sur. 1899. 19th An. Rep't, pt 3, p.407.

2 Gabbro (hyperite), dike near Nicholville, Hopkinton, St Lawrence co. Brief mention by H. P. Cushing. 16th An. Rep't N. Y. State Geol. 1899. p.22. E. W. Morley analyst.

3 Anorthosite gabbro, Carnes's quarry, Altona, Clinton co. Description by H. P. Cushing, analysis by E. W. Morley. 19th An. Rep't N. Y. State Geol. 1901. p.r58.

4 Anorthosite, summit of Mt Marcy, Keene, Essex co. A. R. Leeds analyst. N. Y. State Mus. 30th An. Rep't. 1878. p.92.

5 Anorthosite, Keene township, Essex co. (precise locality not given). A. R. Leeds analyst. N. Y. State Mus. 30th An. Rep't. 1878.

6 Anorthosite showing transition to augite syenite, cut by N. Y. C. & H. R. R. R. nearly 5 miles north of Tupper Lake Junction, Altamont, Franklin co. Description by H. P. Cushing, analysis by E. W. Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r68.

7 Gabbro, intermediate between gabbro and augite syenite and occurring as a basic phase of the latter; from Natural Bridge, Diana, Lewis co. Description and analysis by C. H. Smyth jr. Geol. Soc. Am. Bul. 6:274.

8 Augite syenite from the great intrusion into anorthosite, road from Tupper lake to Wawbeek, ½ mile east of Halfway brook, which marks the line between townships 22 and 23, Franklin co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

9 Augite syenite, cut by N. Y. C. & H. R. R. R. 3½ miles north of Tupper Lake Junction and 1 mile from the first anorthosite outcrops, the latter being of the transition type, analysis 6; Altamont, Franklin co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

10 Gneiss, referred somewhat doubtfully to augite syenite; occurs involved with a later granitic gneiss in the border zone of the augite syenite; from cut by N. Y. C. & H. R. R. R. between Piercefield and Childwold, and 1 mile from the latter; Hopkinton, St Lawrence co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r70.

11 Augite syenite, Loon lake, Franklin co., typical. Description by H. P. Cushing, analysis by E. W. Morley. Geol. Soc. Am. Bul. 10:177-92.

12 Augite syenite, near Harrisville, Diana, Lewis co.; the gabbroic rock, analysis 7, is a differentiation phase of this syenite. Description and analysis by C. H. Smyth jr. Geol. Soc. Am. Bul. 6:271-74; and 17th An. Rep't N. Y. State Geol. 1899. p.471–86.

13 Augite syenite, Little Falls, Herkimer co. Description by Cushing, analysis by E. W. Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

14 Quartz augite syenite, from border zone and accompanied by granite, cut by N. Y. & Ottawa R. R. 2½ miles south of Willis pond, Altamont, Franklin co. Description by Cushing, analysis by Morley. 20th An. Rep't N. Y. State Geol. 1902. p.r69.

Discussion. The gabbros are the most basic rocks of the Adirondack eruptive core, except for their own local, iron-rich differentiations, which give rise to the titaniferous magnetite ore deposits. The two analyses, 1 and 2, represent well their general composition and the usual limits of their variation. They are quite ordinary gabbros and show no differences worthy of mention when compared with most rocks of the sort.

Unfortunately, with the exception of analysis 3, no analyses are available of the transition rocks between the gabbros and the anorthosites, such transition rocks occurring at the borders of the main anorthosite bodies as well as in smaller, separate masses, though the general differentiation of the gabbro and anorthosite must be regarded as having taken place below, in the parent magma of both. The smaller anorthosite bodies, such as those near Keeseville and on Rand hill in Clinton county, the latter furnishing the rock whose analyses appear in column 3, are very

markedly gabbroic. The analysis, however, shows a rock which, in its high alumina and rather low iron and magnesia, is much closer to anorthosite than to gabbro. It, nevertheless, represents an intermediate stage in every single constituent. It was chosen for analysis because of its freshness and in spite of the fact that it appeared to be the most anorthositic portion of the Rand hill body and therefore not a fair representative of its general character. The main rock is a more strictly intermediate one, and the same thing is true of the Keeseville rock and of much of the border of the great anorthosite mass of Franklin county.

As close a calculation as can be made of the mineral composition of the anorthosite gabbro of analysis 3, without analysis of the component minerals, indicates some 70% of feldspar, made up of orthoclase 7.5%, albite 29.75% and anorthite 32%. In addition there are 11.75% of garnet, 7% of augite, 4% of hornblende, 2.5% of magnetite and 5% of quartz. The free quartz is specially noteworthy in so basic a rock, is usually to be found in the anorthosite gabbro of the region, and recalls the quartz norites described by Kolderup as associated with anorthosite in the Ekersund-Soggendal district in Norway. For comparative purposes four of his analyses are appended.

	1	2	3	4	5
SiO_2	53.42	52.61	52.21	53.28	51.62
Al_2O_3	28.36	27.15	19.24	23.3	24.45
Fe_2O_3	1.8	4.05	10.46	7.55	1.65
FeO					5.3
MgO	.31	1.55	2.36	3.02	1.21
CaO	10.49	9.96	7.28	5.01	9.97
Na_2O	4.82	4.53	3.48	3.9	3.49
K_2O	.84	.78	1.09	1.51	1.27

1 Anorthosite (labradorit), Ogne, Norway. Kolderup analyst. Die Labradorfelse des westlichen Norwegens. Bergens museums aarbog. 1896. p.20.
2 Anorthosite norite (labradoritnorit), Ekersund. Kolderup analyst. p.20.
3 Quartz norite, Soggendal. Kolderup analyst. p.16.
4 Quartz norite, Theingsvaag bei Ekersund. Kolderup analyst. p.16.
5 Anorthosite gabbro, Carnes's quarry, Rand hill.

It is to be noted that Kolderup's quartz norites are more typical for the rock than the one analyzed from the Adirondacks, that approaching anorthosite more closely and being more like his

anorthosite norite in many respects. His quartz norites show 10% or more of quartz as against the 5% of the Rand hill rock. But, as has been stated, the larger part of the Rand hill rock is more quartzose than the specimen analyzed and would in all probability approach his quartz norite very closely.

The chemical differences between the anorthosite gabbro of analysis 3 and the anorthosites of 4 and 5 of the original table are slight, 3 showing diminished silica, alumina and soda, and increased iron and magnesia; they suffice however to cause a drop in the feldspar content from over 90% in the anorthosite to 70% in the anorthosite gabbro. In all these anorthositic rocks part of the potash is in the labradorite, replacing a certain amount of soda. Analyses of this feldspar always show it, and, in calculating the rock analyses, it is necessary to assume that part of the calculated orthoclase goes with the albite to form labradorite, in order to bring about agreement between the computation and the observed optical properties of the feldspar.

The rock analyzed in column 6 has the appearance of an intermediate rock in the hand specimen, the feldspar augen resembling labradorite, and being sometimes iridescent, the granular portion having the look of augite syenite. Cleavage fragments from the augen give extinctions of—5° on 001 and—19° on 010, and hence are close to labradorite, Ab_1 An_1. But the granular feldspar is in part microperthite, and in part an acid plagioclase. The alkali percentage is abnormally high for so basic a rock. The total bases bear a very high ratio to the silica and alumina, and the considerable alteration of the augite to a chloritic aggregate renders attempts at calculation of the mineral percentages hazardous. The rock is approximately composed of orthoclase 20%, albite 44%, anorthite 11%, magnetite 4%, and the remainder of augite and garnet in the ratio of 2 to 1, including a little hornblende, apatite and quartz, the latter only as a by-product of garnet formation. In its high alkali percentage and consequent feldspars, the rock distinctly approaches the syenites, though its silica percentage remains that of the normal anorthosite.

The gabbro of column 7 is a most interesting rock. Its occurrence with, and as a differentiation product of an augite syenite body, of which it must be regarded as a basic phase rather than as a true gabbro, and its intermediate position chemically between

augite syenite and gabbro, are very suggestive. Like the intermediate rock of column 6, it departs most widely from both the syenites and the anorthosites in its magnesia percentage, the general Adirondack intrusives being abnormally low in that oxid. It occupies an intermediate position between syenite and gabbro, rather than between syenite and anorthosite, and as such is nearer syenite than gabbro chemically. Through the kindness of Professor Smyth, the writer is in possession of a slide and specimen of this rock. The analysis gives the iron as all in the ferrous condition, but there is quite a little magnetite in the rock, and a rough calculation indicates its approximate composition to be 21% orthoclase, 36.75% albite, 13.75% anorthite, 3% magnetite and 25% augite and hornblende. The feldspar content is quite like that of the preceding rock, the augen consisting of labradorite and the granular feldspar of microperthite and acid plagioclase.

The remaining seven analyses, no. 10 excepted, are all of unmistakable syenite and gave an excellent representation of its variation. The ferrous iron percentage is mostly high, and the results of some of the analyses tend to throw doubt on the reliability of the entire series of ferrous iron determinations, and hence to greatly complicate attempts to calculate the mineral percentages. The two most clearly abnormal results are those of analyses 9 and 13. In the former case the result of the ferrous iron determination exactly equaled the total iron in the rock, yet the thin section showed considerable magnetite present, and a rough separation by means of heavy solutions and a bar magnet proved the presence of at least 5% of that mineral. In the latter case the total iron present is 3.42%, yet the ferrous iron result exceeded 5%. While only these two were on their face erroneous, others, such as nos. 10 and 11, are quite suspicious. The disturbing cause can not be pyrite, since there is so little of it present that the sulfur percentage does not in general reach .01%. It is difficult to see how carbonaceous matter other than graphite can be present, and in an igneous rock any considerable amount of graphite would be surprising. The cause of the vitiation is as yet undetected.

The only analysis so far made of the augite syenite which occurs cutting the anorthosite, analysis 8, indicates that to be

somewhat more basic than the usual rock, and this seems to be true of all such syenite, so far as can be judged by the thin sections. Garnet is much more abundant than in the usual syenite, and bronzite is lacking. The analysis indicates a rock composed of 24.25% orthoclase, 44.55% albite, 5.6% anorthite, 1.7% magnetite, 5.8% garnet, 14.5% augite and 3% quartz. If the ferrous iron be too high, and this is possible, though the discrepancy can not be great in this case, the magnetite and anorthite percentages would be slightly increased and those of augite and quartz diminished. Except for a slight amount of acid plagioclase, the feldspar is all of the intergrowth types, and cleavage fragments from the crushed rock show the optical characters of anorthoclase, viz a + 9° extinction on M, with an acute bisectrix in the center of the field.

The rock used for the next analysis, 9, is from near the anorthosite boundary. Ferro-magnesian silicates are more prominent than usual, considerable hornblende, augite and garnet being present and some bronzite, altogether constituting some 30% of the rock. The lower alkalis show the diminished feldspar percentage, but a calculation is rendered impossible by failure of the ferrous iron determination. On the basis of 5% of magnetite, as indicated by the separation previously mentioned, the calculation gives a silica residue amounting to 13% of free quartz, which is much too high, there being but little present. The remaining analyses require little comment aside from no. 10. No. 11 is regarded as giving the closest approximation to the mean composition of the rock and is from the Loon lake type locality.

The pyroxenes and hornblende which these rocks contain are precisely like those in the anorthosites, strongly suggesting community of origin. The feldspars are alkali feldspars with closely corresponding soda and potash content. In the general rock garnet is a much less conspicuous feature than in the anorthosites, and is often wholly absent. This is but natural, since the garnet is not primary but has resulted from the interaction of feldspar and magnetite. It is a lime-iron-alumina garnet, and the necessary lime for its formation is lacking in the alkali feldspar of the syenite. A further distinction between the two rocks lies in the abundance of zircon in the syenite. It

by no means rises to the dignity of an essential constituent but is much more abundant and attains a larger size than in the usual igneous rock. The syenites contain quartz almost without exception, and the amount increases toward the acid end of the series, the calculation of the analysis of column 14 showing 14% of that mineral.

Analysis 10 is of a green gneiss which occurs associated with granite and granitic gneiss near Piercefield. Its field relationships to the syenite are not plain, and the doubt about its properly belonging with them is not cleared away by the analysis, which falls slightly out of the series in its magnesia-lime ratio and in its total magnesia. The rocks nearest it in silica percentage, 8 and 9, have this ratio, 1:3 and 1:3.5 respectively, as against 1:1.7 in 10. Its ratio is nearest to that of 13. On the other hand, it can be argued that its general great similarity in composition would seem to ally it closely with the syenites, and that these show a great variation in the magnesia-lime ratio, even though it approaches so near to equality in no other.

General characters of the Adirondack eruptives. The analyses in the preceding table are thought to be sufficiently numerous to furnish a very fair representation of the general characters of the Adirondack eruptives, except for the lack of analyses of the granites. The latter vary greatly, ending with very acid rocks composed almost wholly of quartz and feldspar. It is quite safe to say that they will reach 75% of silica and probably higher, and that, since their feldspar is universally microperthite, the ratio of soda to potash will remain substantially as it is in the syenites.

The gabbros and anorthosites are quite normal representatives of these groups. But in the transition rocks between these and the syenites we find low magnesia, low ratio of lime and magnesia to alkalis, and approximately equal amounts of soda and potash, and these characters continue to the end of the series. The soda-potash ratio is a slowly changing one, the potash being at first below, but eventually overhauling and passing the soda in the more acid rocks. In these respects the syenites, and probably the granites, depart somewhat from the corresponding rocks of the Ekersund-Soggendal area in Norway, which also ac-

company anorthosite and gabbro, and which Kolderup has so exhaustively described. In general the Adirondack syenitic rocks run higher in the alkalis and lower in lime and magnesia than the corresponding Norwegian rocks. These differences are but slight, and the general agreement between the two series is very close, but they point to a slight original difference in the character of the parent magma of the two districts. The appended analyses bring this out clearly.

	1	2	3	4	5	6
SiO_2	57	57.11	63.45	64.35	68.5	70.33
Al_2O_3	16.01	17	18.38	15.46	14.69	15.59
Fe_2O_3			.42		1.34	1.4
	10.3	12.48		7.5		
FeO			3.56		3.25	1.54
MgO	1.62	1.78	.35	.5	.26	1.3
CaO	6.2	3.99	3.06	3.58	2.2	3.05
Na_2O	4.35	3.96	5.06	3.28	3.5	4.5
K_2O	3.53	2.59	5.15	3.54	5.9	1.29
H_2O	.15	......	.3	......	.4	......
TiO_2	......	1.59	.07	1.63	......	.85
ZrO_2	......	......	......	......	MnO .1	.24
BaO	......	......	.13	......	.05	......
Total	99.16	100.5	99.73	99.84	100.22	100.09

1 Basic syenite from Natural Bridge; 7 of previous table.

2 Monzonite from Fuldland near Farsund. Description and analysis by C. F. Kolderup. Die Labradorfelse des westlichen Norwegens, Bergens museums aarbog. 1896. p.129.

3 Augite syenite from Loon lake; 11 of previous table.

4 Banatite from Dypvik near Farsund. Die Labradorfelse des westlichen Norwegens, p.123.

5 Quartz augite syenite from near Willis pond; 14 of previous table.

6 Adamellite from Farsund. Die Labradorfelse des westlichen Norwegens p.115.

So far as their mineralogy is concerned, the Adirondack rocks would fall without question in the monzonite group. The prevailing feldspar is microperthite in which the plagioclase molecule is constantly in excess of the orthoclase, so that they are strictly plagioclase orthoclase rocks. The table brings out the chemical differences, which would seem mainly due to the fact that the plagioclase in the microperthite is albite in the Adirondack rocks and oligoclase in the Norwegian. Certainly the

Adirondack rocks closely approach the monzonite type. They also closely approach Brögger's akerite type (quartz augite syenite) from near Christiania, and seem to occupy a position intermediate between the two. Smyth's rock from Natural Bridge, column 1 of the above table, would certainly fall within the monzonite group, notwithstanding its high lime percentage; and the rock from north of Tupper lake, column 9 of the original table, belongs also in that group lying on the border land between monzonite and banatite.[1] Because of this, it is perhaps more logical to refer all the Adirondack syenite to that group, though as a somewhat aberrant type.

It would therefore appear that in each district a very similar magma has given rise to a very similar rock series, and, it is likely, through a similar differentiation process. The order of succession of the different types can not be compared, since the Adirondack succession is uncertain in one respect. The syenite followed the anorthosite, and then came the granite, but the position of the gabbro is uncertain. It is certainly later than the anorthosite, and certain gabbroic dikes which have been found cutting the syenite lead to the impression that it is later than that, but there is some question as to the correctness of their reference to the main gabbro of the region. There may have been two periods of gabbro outflow, one earlier and the other later than the syenite.

A few dikes, and a few small eruptive masses, of three or four different types, have been noted which are not referable to any of the great masses apparently. But as yet their relationships are obscure. All are younger than the anorthosite, and all are metamorphosed.

General metamorphosed condition of the intrusives. All these igneous rocks have undergone severe metamorphism, as shown by the partial or complete granulation of the original minerals, the large amount of recrystallization, and the production of

[1] The monzonite group was established by Brögger to contain rocks intermediate between the granite syenite group (orthoclase rocks) on the one hand, and the diorite gabbro group (plagioclase rocks) on the other; hence characterized by both orthoclase and plagioclase. Monzonite has a silica percentage between 50% and 60%, banatite between 60% and 66%, and adamellite over 66%.

foliation in varying degree. In all of them the amount of change varies from place to place. In a rude degree all the intrusive masses show greater metamorphism toward their edges than at their centers, and because of this the large masses are apt to show a larger proportion of slightly metamorphosed rock than the small masses do. All of them also show local variations in this respect. As a general rule the anorthosite is the least metamorphosed of all the intrusives. If it were younger than the others, its condition in this respect would find ready explanation; and, not only that, but its condition furnishes a perfectly valid argument in favor of its younger age. Such evidence as exists that it is the oldest, rather than the youngest of the intrusives, has already been given in detail, and, if this be the case, other evidence must be produced to account for its apparent lesser degree of metamorphism. This evidence is of threefold character and derived from the distribution, the original texture and the composition of the rock. The main anorthosite of the district occurs as a single great intrusive mass, while the other intrusives are found in a number of smaller, disconnected masses, hence, for the reason just outlined, the rude relationship between size of intrusion and thoroughness of metamorphism, the anorthosite should in general be less metamorphosed than the others.

The anorthosite was originally a vastly more coarsely crystalline rock than were any of the other intrusives. The granulation of these rocks begins at the margins of the separate crystals and works inward by degrees, so that the amount of granulation necessary to completely obliterate the original crystals is, other things being equal, dependent on their size, since the smaller they are the more margins there are where the process can be initiated, and the greater the rapidity of destruction.

The anorthosite has also a simpler mineral composition than the other intrusive rocks, since it is mainly or wholly made up of the one mineral, labradorite. Hence there is afforded comparatively little opportunity for the development of new minerals by corrosion, so that recrystallization has not gone on to the extent that it has in the other rocks, and in so far as it has occurred, can mostly only give rise to more labradorite.

With the passage of the rock into anorthosite gabbro, recrystallization always comes much more largely into play, because of the more varied mineral composition, facilitating corrosion and causing more or less foliation. It is thought that there is here a reasonable and likely the true explanation of the *apparent* less metamorphosed condition of the anorthosite.

The Grenville and Saranac rocks are apparently more thoroughly metamorphosed than the later intrusions. They are more uniformly granular, better foliated, much more completely recrystallized and with a usual utter lack of all traces of original textures. These same characters are also found in the inclusions of these rocks which occur in the intrusives and seem to the writer to indicate that they were somewhat metamorphosed, at least, before the time of the intrusions. While no doubt the heat and pressure incident on their intrusion must have exerted considerable effect on the older rocks, the evidence does not point to this as of prime importance in their metamorphism.

But the distinction between the two sets of rocks is in many ways not a sharp one and is difficult to apply. The more thorough foliation and complete recrystallization of the Grenville rocks may be accounted for by the fact that they were originally fine grained sedimentary rocks, and that their metamorphism is not necessarily more extreme than that of the intrusives. But the more metamorphosed character of the igneous Saranac rocks can not thus be accounted for. The whole problem of their age and relationships is one of such uncertainty however that it is somewhat unsafe to emphasize comparisons between them and the intrusives. They are cut in places by small masses of the intrusives and they must occur as inclusions in them. The difficulty of the whole matter arises from the fact that the Saranac rocks are so similar to the more gneissoid phases of the granite, syenite and gabbro masses that it is frequently impossible to tell with which rock one is dealing. Small, later intrusive masses in the Dannemora rocks may be so thoroughly gneissoid as to appear like an integral part of the group. Specially among the granitic Saranac gneisses traces of cataclastic structure are often found, and of igneous textures; yet

one can seldom be sure in such cases that one is not dealing with a later intrusive.

That there are igneous gneisses in the region which are older than the anorthosite is certain, since such rocks are found cut intrusively by it. That these rocks are for the most part thoroughly gneissoid, more so than is true of any of the larger intrusive masses, is also certain. It would therefore seem that they must have been somewhat metamorphosed before the appearance of the intrusives, but that the criterion is not one which can be used in all cases for the purpose of discriminating between the two sets of rocks.

If the intrusion of the great igneous masses had been the prime factor in the metamorphism of the older gneisses, their foliation should show a general parallelism to the boundaries of the intrusions. In general it does not show this, but on the contrary is mostly independent in direction. Adams has described a notable instance in Canada, where the strike of the foliation of the gneiss around the Morin anorthosite rather minutely parallels the boundary on three sides of the mass.[1] But it does not follow it on the fourth side, the anorthosite is also foliated near the boundary, and its foliation everywhere parallels that of the gneiss, and Adams regards it as having been produced in both at the same time, and necessarily subsequent to the intrusion.

No similar case of striking parallelism has been noted in the Adirondacks so far as the writer is aware, and it is also true here that locality for locality, the foliation of the older gneisses and of the intrusions corresponds, indicating that it is due to a common cause, operating after the appearance of all the intrusives, since they all show foliation. It is no doubt true, as urged by Adams, that the contact lines between the two sets of rocks will form lines of weakness, along which there will be a special tendency to stretching, and which may locally influence the direction taken by the foliation, when not overbalanced by other things. But so far as the writer's observation in the Adirondacks goes, parallelism is the exception rather than the rule.

The universal concordance in foliation between the gneisses and the intrusives makes it impossible to say whether the former possessed any previous foliation or not. If so, it was either

[1]Geol. Sur. Can. 8:13J-15J.

destroyed by the later metamorphism, or else the two pressures came from the same direction, and the later foliation was superimposed on the earlier, this being much the more probable of the two.

It has previously been stated that the character of the metamorphism which these rocks have undergone is indicative that they must have been deeply buried at the time of metamorphism. The igneous rocks specially are rocks of the most massive and resistant sort; yet over a large part of the region their constituent crystals have been broken up into a mass of granular fragments, accompanied by much recrystallization. The rock masses have also been shortened in the direction of greatest pressure and extended in the plane at right angles to this, with the production of foliation in this plane; and all this has taken place under such great load that no permanent cracks could form, all breaks being closed up by welding as soon as formed, so that the rocks have in general not been weakened and have often been made stronger by the process. The depth below the surface at which permanent cracks can not exist is considerable and moreover varies with the nature of the rock concerned, being greatest for strong, massive igneous rocks of this character. Yet during metamorphism these rocks were at that depth. The change in shape has been effected by actual movement of the rock particles, so that the rock must have been sufficiently loaded to be plastic. Large feldspar crystals have been bent through considerable angles without breakage. Quartzes have been drawn out into long lenses and spindles. A multitude of phenomena showing stretching of the rock, accompanied by actual flowage of the material, could be cited, yet the strength of the rock has not been impaired. The rocks have been under a pressure whose amount exceeded their ultimate strength, and under a load sufficient to cause welding up of all cracks. The exact depth of burial necessary to bring about these conditions in rocks of this sort is uncertain, but a depth of 5 miles is probably not more than a mile or two wide of the mark in either direction.

As near as can be judged from the small and scattered Grenville exposures in the heart of the district, their foliation is everywhere parallel to the original bedding. It is also true that, over much of the district, the foliation dips are compara-

tively flat, though no such striking instance has been met with as Adams has described in Canada.[1] The general foliation strike in the Adirondacks is n.e. and s.w., and the usual dip is to the east, though there are many exceptions to both rules. In some districts there is evidence of considerable folding of the bedding and foliation planes but it is seldom sharp, and intricate folding and plication occur seldom, if ever. Van Hise has suggested that the development of foliation parallel to bedding may have been initiated by vertical shortening and horizontal elongation below the level of no strain, or of no lateral stress, and that in subsequent compression and folding the varying strength of the different beds controlled the movement and kept it in the same planes.[2] This is an ingenious and very plausible suggestion, the likelihood of which is emphasized by the many evidences of the deep seated character of the metamorphism. But the uniformity of direction of foliation in both sedimentary and igneous rocks shows that the metamorphism which produced it followed the appearance of the igneous rocks, and that it must have been produced in both at the same time.

Late Precambric igneous rocks. Dikes of two sharply contrasted sorts of rocks are of frequent occurrence in parts of the Adirondack region, cutting all of the rocks so far described. They are of all widths up to over 100 feet, though those wider than 30 or 40 feet are exceptional, and few reach those dimensions. The larger number have an approximate east and west trend and are nearly vertical. The more common dikes are of a black, flinty, basic rock, diabase; the others are more variable, but are usually quite acid, red, porphyritic rocks of syenitic make-up.

They are much more abundant in the northeast than in any other part of the region, being exceedingly numerous in Clinton county and northern Essex, so much so that, if massed together, it would be at once evident that they constitute a very respectably large portion of the whole rock mass. Somewhat less than half of Clinton county has Precambric surface rocks, yet some 130 of these dikes are known in the county and there are doubtless many more. Rand hill, Dannemora mountain and

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[1] *Op. cit.* p.11J-12J.

[2] U. S. Geol. Sur. 16th An. Rep't, pt. 1, p.773.

the shores of Upper Chateaugay lake may be mentioned as localities where they are exceedingly numerous. Followed to the south and west, they rapidly diminish in number and become rare or wholly absent. Thus Kemp reports many from Essex county, mainly in the north, but very few from Washington and Warren. Franklin county is much larger and with a proportionate much greater area of Precambric rocks than Clinton, yet only some forty of these dikes have been discovered there, and these mainly in the eastern portion. Though many more doubtless remain undiscovered, the relative abundance can be calculated, and they are six to eight times as abundant in Clinton as in Franklin. In St Lawrence, Hamilton and Herkimer counties they are practically absent, and the few known are toward the northeast. Smyth reports them in comparative abundance in the Thousand islands region on the west border of the district, and a single large dike of diabase is found in the Little Falls outlier on the far south. So far as the present Adirondack region is concerned, the igneous activity of this time centered in Clinton county, dying out toward the south and west. As to the extension northward and eastward, nothing can be stated, since the Precambric rocks pass under a paleozoic cover in those directions. Diabase dikes are however fairly abundant in Canada in the region beyond this cover.

The centering of the activity in Clinton county becomes the more apparent when the distribution of the two varieties of the dikes is taken into consideration, the red, syenite dikes being practically confined to that county. They are far less numerous and of much more restricted distribution than the diabases. Only 26 dikes of this class have been noted, of which 19 are on Rand hill, where exposures are numerous and detailed work has been done. No doubt there are many others elsewhere, but it seems quite certain that they are practically confined to the county, only one having been noted outside its limits, and that in Franklin not far from the boundary. Even on Rand hill the diabases much outnumber them. The display of dikes there is the most impressive known in the Adirondack region. If any volcanos were built at the time, surely the roots of one gigantic one are here.

A .as already been stated, these rocks are found at the present

time only in dikes. We see the channels through which the material ascended, but can not be sure whether any reached the land surface of the time, giving rise to true volcanic action, nor do we anywhere get a glimpse of the underlying reservoirs which supplied the material, since erosion has nowhere cut deeply enough to disclose them. It may well be, therefore, that the mere dikes give little idea of the possible importance of this period of igneous activity. But, if great surface flows occurred, or volcanos were formed, it seems strange that no vestiges of their presence remain, since, as has been stated, the character of the dikes themselves does not indicate any very great amount of erosion of the present surface as compared with that of that time. The most of the erosion since has been expended on the paleozoic cover which subsequently overspread this old land surface.

These dikes apparently owe their existence to the same causes which were responsible for the earlier, great intrusions, and mark the last paroxysm of igneous activity from that source. They are wholly unmetamorphosed and are the only Precambric rocks in the region of which this is true. Moreover, in cooling, the chilling influence of the walls has been very marked, indicating comparatively near surface conditions at the time. The borders of even the largest dikes have cooled so rapidly as to be glassy, though the rock may become quite coarsely crystalline toward the center. Little or no trace of such strong, chilling effect is to be found in the older dikes of the region. Occasionally the dikes are even somewhat amygdaloidal, which is also indicative of cooling at no great depth. These characters point conclusively to a much younger age for these dikes. Their time of appearance was not only subsequent to the great metamorphism of the region, but was near the close of the following long period of Precambric erosion. Before their appearance the rocks which they cut had had the greater part of the overlying load of material which covered them during metamorphism, laboriously pared away by the slow processes of erosion, a depth of erosion being involved which necessarily argues the lapse of a vast interval of time.

These rocks are very similar to those of the igneous outflows which characterized Keweenawan time (supposedly late Pre-

cambric) in the upper Great lakes region, and it is thought that they are of approximately the same age.

In only one case has it been possible to make a relative age determination between the two sets of dikes. Near the summit of Rand hill a 15 inch dike of the syenite porphyry, bearing n.65°e., is cut by a diabase dike of the same width bearing e. and w. In this case the diabase is indisputably the younger. While this does not demonstrate that all the diabase is younger than all the syenite porphyry, it at least points strongly to such a conclusion.

Syenite porphyries. The rocks from the various dikes differ considerably. Nearly all of them show porphyritic feldspars, though with much variation in size and abundance. These are usually red, but become greenish in one dike, and in another are of a red violet hue. Except in one dike this is the only porphyritic mineral, biotite also appearing in this case. The dikes are often of pronounced red color, but some are much darker, gray to black, with often a greenish tinge when slightly altered. The narrower dikes are dense, hard rocks with conchoidal fracture and aphanitic appearance and general red color. The larger ones are equally hard and firm, but coarser grained and less apt to be red.

These rocks are essentially composed of microperthitic feldspar and biotite, with accessory magnetite (or specular hematite), hornblende, quartz, albite, orthoclase, microcline, apatite and titanite, and with secondary chlorite, calcite, muscovite, epidote and hematite. Microperthite and chlorite, the latter from biotite alteration, are the only minerals present in all the dikes. Quartz is present in most of them, in quantity varying with the composition. The ground-mass has in general a well marked flow (trachytic) structure.[1]

They show a surprising range in composition considering their rather constant mineralogy, varying from the acidity of granites to, in the case of one dike, a basicity approaching that of basalt.

Diabases. The numerous dikes of this rock in the Adirondacks exhibit many variations in composition and texture, and on the northern slopes of the north foothills of the region, where glacial erosion was powerful and all weathered rock was swept

[1]For detailed description, *see* Geol. Soc. Am. Bul. 9:239–56.

away, they are often found in beautifully fresh condition. They have not, as yet, received the thorough description which they merit, Kemp's account of them being the most exhaustive which has yet appeared.[1]

The usual diabases consist essentially of a plagioclase feldspar, mostly either andesin or labradorite, augite and magnetite. To these olivin must be added in a very large portion of the dikes, the number of olivin diabases equaling or exceeding that of those without this mineral, so far as the writer's observation goes.

The smaller dikes are, almost without exception, porphyritic, and the same is true of at least the borders of the larger ones, though these frequently become sufficiently coarse grained in their central portions to cause this character to lose its distinctness. As a general proposition, the dikes may be said to be characterized by two generations of one or more of the minerals present, sometimes the feldspar alone, sometimes the augite alone, sometimes both, occurring in this way. The olivin, when present, seems always to belong to the first generation.

Three of the Franklin county dikes are notable in containing an orthorhombic pyroxene, bronzite, in considerable quantity. It is porphyritic in all, and with its coming in, olivin retreats. In two of them, it gives rise to beautiful parallel growths with augite of a certain sort, nearly all the bronzites being bordered by a narrow zone of this mineral, after the usual law of such growths. The augite plainly did not begin to form till the period of bronzite formation had passed, and the crystals furnished nuclei favoring augite growth.

In some 25% of the dikes biotite is present, occurring in frequent small scales in the ground-mass, with a notable tendency to border the magnetite crystals. In such situation it has been sometimes regarded as primary and sometimes as a result of magnetite-feldspar corrosion. Kemp looks on it as the former, in the Essex county dikes. The writer has been unable to satisfy himself as to which view is the proper one, in the case of his own dikes, though disposed to the latter view.

That these rocks show a notable range in composition is indicated by the considerable variation in the relative amounts of feldspar and augite, the former being very materially in excess

[1] U. S. Geol. Sur. Bul. 107, p.24-27.

in some of the rocks and the latter predominating in others. The olivin diabases are in general less feldspathic than those in which that mineral is lacking. Much variation in structure is also shown which, to a considerable degree at least, depends on composition. The ophitic structure is the more usual one. In many of the dikes, however, the interspaces between the feldspar laths are filled by clumps of smaller augites, instead of the large augites which solidly fill the interspaces in the typical structure. In the more feldspathic dikes the interference of the different feldspar laths with one another, and their abundance much hinder the development of the normal structure.

In many of the dikes there is a more or less well marked tendency on the part of the feldspar laths to assume a radial grouping around various centers, giving rise to the divergent rayed structure. In some such the augites also tend to a long prismatic, or lath, shape, and these may take on an independent radial grouping also. A tendency on the part of the augites to show their own crystal boundaries is found in many of these rocks, as Kemp has shown, producing a grading toward camptonite.

Chemical analyses and discussion

	1	2	3	4	5	6	7	8	9
SiO_2 . . .	43.41	44.51	45.46	46.73	50.89	52.53	63.02	67.16	68.96
Al_2O_3 . . .	19.42	19.99	19.94	16.66	15.39	18.31	14.87	14.53	15.25
Fe_2O_3 . .	5.72			3.56		.34	6.53		3.28
		7.22	15.36		5.77			4.17	
FeO . . .	6.691			8.45		6.43	none		none
MgO . . .	5.98	8.11	2.95	8.12	7.6	1.82	.95	.41	.2
CaO . . .	9.11	8.15	8.32	8.03	8.75	3.15	1.12	1.26	.76
Na_2O . . .	4.39	5.24	2.12	3.73	5.67	7.26	5.85	5.55	5.45
K_2O	.47	2.6	3.21	1.64	2.72	6.47	5.62	6.1	5.01
H_2O	3	2.93	2.3	2.39	2.46	1.16	1.45	1.1	.91
TiO_2 . . .	.35	. . . . .	. . . . .	.03	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
P_2O_5 . . .	. . . . .	. . . . .	. . . . .	.39	. . . . .	1.59	. . . . .	. . . . .	. . . . .
Cl	. . . . .	. . . . .	. . . . .	.18	. . . . .	.4	. . . . .	. . . . .	. . . . .
F	. . . . .	. . . . .	. . . . .	.26	. . . . .	.32	. . . . .	. . . . .	. . . . .
Cr_2O_3 . .	. . . . .	. . . . .	. . . . .	.06	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
MnO . . .	. . . . .	. . . . .	. . . . .	trace	. . . . .	.15	.46	. . . . .	.23
BaO . . .	CO_2-2	. . . . .	. . . . .	.04	. . . . .	. . . . .	. . . . .	. . . . .	. . . . .
Total . .	100.54	98.75	99.66	100.2	99.25	99.93	99.87	100.28	100.05
O=Cl & F.				.14		.22			
				100.06		99.71			

1 Diabase from summit of Mt Marcy, Essex co. Analyst Leeds. N. Y. State Mus. 30th An. Rep't, p.102.

2 Diabase from shore of Upper Chateaugay lake, Clinton co. Analyst Eakle. Am. Geol. July 1893, p.35.

3 Diabase from Palmer hill, Black Brook township, Clinton co. Analyst Kemp. U. S. Geol. Sur. Bul. 107, p.26.

4 Olivin diabase, Bellmont township, Franklin co., dike 13. Analyst Morley. 18th An. Rep't N. Y. State Geol. p.120, and 20th An. Rep't, p.r79. Very fresh, olivin not perceptibly serpentinized.

5 Olivin diabase from shore of Upper Chateaugay lake, Clinton co. Analyst Eakle. *Op. cit.* p.35.

6 Very basic syenite porphyry, Rand hill, Clinton co. Analyst Morley. Geol. Soc. Am. Bul. 9:248.

7 Normal syenite porphyry, Rand hill, Clinton co. Analyst Morley. *Op. cit.* p.248, and 20th An. Rep't N. Y. State Geol. p.r79.

8 Syenite porphyry from shore of Upper Chateaugay lake. Analyst Eakle. *Op. cit.* p.34.

9 Acid syenite porphyry, Rand hill, Clinton co. Analyst Morley. *Op. cit.* p.248 and r79.

The analyses quoted above are all that are known to the writer of these rocks. Many of them are quite old but are valuable for comparative purposes, though not going into the minutiae of modern requirements. The diabases show considerable variation, as would be expected, yet on the whole harmonize well with one another. No. 4 is the only tolerably complete analysis, and at the same time seems to represent about a mean between the extreme types and will hence serve as a fair representative of the average diabase of the district. It consists essentially of labradorite and augite in about equal amounts, with considerable olivin and magnetite and a rather unusual amount of biotite, much of which is clearly primary. Apatite is about the only other mineral. The magnetite is only slightly titaniferous, if at all, since the very small amount of titanium present may likely all be in the biotite. The augite is in two generations, but the feldspar not. The structure is only poorly ophitic.

No. 1 is the rock long ago analyzed by Leeds, the analysis not being accompanied by any description however. Augite is the only mineral specifically stated to be present.

No. 2, according to Eakle, appears to lack olivin, and the augite is almost wholly altered to chlorite and epidote. No. 5, according to the same author, is an ordinary olivin diabase, though he makes no mention of augite, and it is only inferentially supposed to be present. It is noteworthy in being exceptionally acid for

these rocks, though the description does not suffice to bring out the cause for this extra acidity.

No. 3, Kemp's Palmer hill rock, is exceptional for the region in that the feldspar is altered to scapolite, and it falls badly out of the series in several respects, notably in its low magnesia and its excess of potash over soda.

The rocks from which analyses 6, 7 and 9 were made, were selected to represent the mean and the extreme phases of the syenitic dikes. No. 6 is much more basic than any other of these rocks known in the region, a silica determination of the one which seemed to approach it most closely showing 59.2%. From this figure to the 68.96% of no. 9 there is apparently no break in the series.

This basic rock consists essentially of feldspar, a portion of which is microperthite and the remainder albite, biotite, apatite and a little magnetite, these in order constituting 61%, 33%, 4% and .5% of the rock. Except for the absence of quartz these are the same minerals which characterize the other dikes, thus indicating the genetic connection of this rock with the others.

No. 7 consists of feldspar, largely microperthite, chloritized hornblende, magnetite and quartz, with a little apatite and much hematite stain. There is about 10% of hornblende and somewhat less than that amount of quartz in the rock, practically all the remainder being feldspar. Except that in most of the dikes the hornblende is replaced by biotite, this is rather closely the average composition of all.

The rock of column 9 is composed of microperthite, quartz and specular hematite, with exceedingly slight amounts of chlorite and apatite. The feldspar makes a little under 80%, the quartz a little over 17% and the hematite a little over 3% of the rock. The feldspar is very typical microperthite or anorthoclase, composed of orthoclase and albite in the proportion of 2:3.

The likelihood that the material of these dikes was derived from the same magmatic source as that of the earlier great intrusions is strongly suggested by a comparison of analyses.

	1	2	3	4	5	6
SiO_2	47.42	46.73	63.45	63.02	68.5	68.96
Al_2O_3	17.34	16.66	18.38	14.87	14.69	15.25
Fe_2O_3	4.91	3.56	.42	6.53	1.34	3.28
FeO	10.22	8.45	3.56	none	3.25	none

	1	2	3	4	5	6
MgO	5.21	8.12	.35	.95	.26	.2
CaO	8.09	8.03	3.06	1.12	2.2	.76
Na_2O	3.48	3.73	5.06	5.85	3.5	5.45
K_2O	1.89	1.64	5.15	5.62	5.9	5.01
H_2O	1.13	2.39	.3	1.45	.4	.91
TiO_2	3.6	.03	.07	......	......	......
P_2O_5	.06	.39	......	......	.03	......
Cl	.21	.18	......	......	......	......
F	......	.26	......	......	......	......
Cr_2O_3	......	.06	......	......	......	......
MnO	.06	trace	trace	.46	.1	.23
BaO	.04	.04	.13	......	.05	......
Total	100.06	100.2	99.73	99.87	100.22	100.05
O=Cl & F	.05	.14				
	100.01	100.06				

1 Gabbro (hyperite) from near Nicholville, St Lawrence co.; no. 2 of first table of analyses.
2 Diabase, Bellmont township, Franklin co.; no. 4 of second table.
3 Augite syenite, Loon lake, Franklin co.; typical; no. 11 of first table.
4 Normal syenite porphyry, Rand hill, Clinton co.; no. 7 of second table.
5 Quartz augite syenite, near Willis pond, Franklin co.; no. 14 of first table.
6 Quartz syenite porphyry, Rand hill; no. 9 of second table.

A comparison of the first two of the above analyses shows a very close agreement between the gabbro and the diabase in composition, the most striking discrepancy being in the titanium percentage. This difference is perhaps sufficiently pronounced to throw some doubt on the magmatic relationship, since in other respects the analyses might be duplicated from many parts of the earth's surface, both gabbros and diabases of this approximate composition being among the most widespread of igneous rocks. If this high titanium percentage was characteristic of the rocks of the big intrusions, it should appear in the diabases, also if they are congenital. But, so far as the analyses go, they do not indicate a high titanium percentage in the big intrusions except in the basic gabbros, and most of the analyses which have been made of them are from specimens taken from the wall rocks of titaniferous ore bodies, which are segregations from the magma which are extra rich in iron and titanium. It is therefore thought likely that this difficulty in the way of ascribing magmatic relationship is more apparent than real.

The syenite porphyries are somewhat lower in lime and higher in alkali percentage than the corresponding syenites. But the differences are not thought to be sufficiently large to condemn a reference to the same parent magma.

Paleozoic rocks

Potsdam (Cambric) sandstone. Lying uncomformably on the old and much eroded Precambric surface, a great sandstone formation appears, on the north and east and on the eastern half of the southern border of the Adirondack region. This is a water-deposited formation, and, so far at least as its upper portion is concerned, a marine formation. It is thickest on the northeast, thinning out to disappearance both to the south and west. As, furthermore, it appears to be the upper beds which persist, and the lower ones which disappear in these directions, it seems certain that, so far as the immediate region is concerned, the marine invasion came on it from the northeast and extended progressively southward and westward.

In Clinton county, where the formation is thickest, the basal portion is rather sharply differentiated from the rest in character, and this portion has considerable thickness, though how much, and how large a part of the whole thickness it constitutes, is wholly uncertain. The writer was the first to show this, and it has lately been reaffirmed by van Ingen.[1] This portion consists in part of coarse basal conglomerates, in part of poorly indurated sand beds of small durability and in smaller part of thoroughly indurated sandstones. It is nearly everywhere characterized by a considerable feldspar content, in addition to the quartz, and this feldspar is for the most part fresh. Considerable magnetite also appears in places, along with grains of garnet and occasional zircons. The rock has therefore an arkose character in this portion, while above it is prevailingly of pure quartz sand. Red is the predominant color of the base, and there is but little white sandstone in it, while above the latter is the prevailing color. As a general proposition, a feldspar content and a prevalence of red beds go together and are certain signs of the basal portion.

[1] N. Y. State Mus. Bul. 52, p.543.

Basal conglomerates are a prominent feature in Clinton county wherever the proper horizon is exposed. For the most part these are not extra coarse, the larger pebbles seldom exceeding an inch in diameter. The pebbles are prevailingly or exclusively of quartz, derived from the quartz veins of the Precambrian rocks, and are embedded in a coarse sand matrix in which there is a large feldspar, and considerable magnetite content. Along most of the northern border the general lack of pebbles of the underlying rocks, which are mostly Saranac gneisses, is indicative of quite prolonged wear of the material, so that only the extraresistant pebbles of vein quartz origin were sufficiently durable to persist as pebbles. The undecayed character of the feldspar grains of the sands in these conglomerates indicates that all soil and largely weathered rock had already been removed and carried offshore to be deposited, and that the waves were working on tolerably fresh rock, whose grinding to sand had to be performed by water action alone, unaided by any special weakness due to previous weathering.

In some few localities conglomerates indicative of much less vigorous wave action are found. These contain numerous pebbles of the underlying gneisses, often of large size and showing great variation in size, and quartz pebbles are much less conspicuous or lacking. These seem to be purely local deposits laid down in sheltered hollows in the Precambric floor, whose presence is likely due to uneven depth of weathering of the floor rocks. It is in rocks such as these that the pebbles of diabase and syenite porphyry which demonstrate the Prepotsdam age of these dikes, are found. Such conglomerates are much less resistant rocks than the commoner quartz pebble conglomerates, and present exposures usually show them in much disintegrated condition.

These heavy basal conglomerates are mainly confined to the northern border of the region, extending as far west as eastern St Lawrence county. South of Clinton county, along Lake Champlain, their existence is rather problematic, owing to dearth of exposures of the proper horizon, mainly due to faulting.

An interesting outcrop of basal conglomerate occurs not far west of Keeseville in Clinton county, nestling in an indentation in the eastern edge of the anorthosite gabbro, the actual contact

not showing. It is capped by red, feldspathic sandstones of the ordinary basal type. The conglomerate carries numerous quartz pebbles, up to 2 inches in diameter, along with occasional smaller ones of diabase, and of red orthoclase feldspar, the latter clearly from pegmatite veins. The coarsely granular matrix looks black when fresh, becoming green mottled with blotches of chloritic material on weathering. Along with the quartz in the matrix is much microperthite feldspar, considerable magnetite in streaks, and occasional grains of titanite and microcline, all these grains being surrounded by a greenish, chloritelike cement, whose exact nature is not clear.

This conglomerate represents an intermediate stage between the normal, quartzose conglomerates and the local, disintegration conglomerates of the hollows. It is therefore of interest to note that, while it lies in contact with anorthosite gabbro, with no gneissic outcrops within a mile, it is entirely made up of gneissic debris. This may either argue transportation of the materials for at least this distance, which would imply great strength of wave action; or else that gneiss occurred near at hand along the old shore, became covered up by later Potsdam beds, and has since been faulted out of sight. There is no question about the necessary fault being near at hand, and, so far as the writer knows, no evidence which will enable a decision one way or the other.

Very abundant also in the basal portion of the formation, are beds of rapidly disintegrating, very red, coarse arkose sandstones, made up mainly of quartz and feldspar grains and the whole much permeated with red hematite. They break down rapidly to a red, sandy clay, a characteristic soil which is produced by no other rock in the district, and which often shows the presence of these beds when actual outcrops are lacking. Beds of this sort often occur interbanded with the basal conglomerates, or they may constitute the larger part of the base, conglomerates being scarce or absent, as is the case on Rand hill, where these beds show greater bulk than in any other known locality.

Well indurated, red sandstones, such as those from the type locality at Potsdam, are not infrequent in the basal portion of

the formation and are numerously exposed at various localities on the north border of the Adirondacks in such situation as to indicate clearly their horizon. At Potsdam itself the section is complicated by faulting, and the horizon of the red sandstone there can not be demonstrated, though inferentially it is low in the formation. Along with the red there is much hard, glassy, brown sandstone, also containing fresh feldspars, but lacking the hematite coloration of the red beds. Above, the reds become striped and mottled with white, forming a species of passage beds to the middle division.

Van Ingen is the only observer who has undertaken to differentiate between the middle and upper portions of the Potsdam. He says:

> The middle portion of the sandstone is made up of well sorted materials, of finer grain, compactly cemented, and of white, steel gray or yellowish color, with very little or no feldspathic content. The grains of sand are both angular and rounded, with the former predominating. The layers are more regular, though their surfaces are ripple-marked, and in section they are seen to be almost universally cross-bedded. Pebbles are found on the surfaces of some layers of the middle portion, but unlike those of the upper portion they seem to have been of soft mud derived by erosion of contemporaneous sediments, cast on the beach at times of rough water and flattened and squeezed out by the subsequent pressure and consolidation of the superimposed sand deposits.
>
> The upper portion of the formation has frequent beds of irregular laminated sandstone, with partings of greenish arenaceous shale. The shale surfaces are covered with fucoids and worm trails. Pebbles of shale and dolomite, which were hardened before the time of their entombment, are found embedded in the sandstone layers, and their disintegration causes cavities to form in the layers containing them. The dolomite pebbles become more abundant toward the upper horizons. In the upper levels frequent beds are composed of nicely rounded grains of clear quartz with a little cement, that crumble to a sugary powder under the hammer. Rounded grains of quartz of a slightly larger size occasionally cover the upper surface of a layer of finer grained sandstone, and, being without cement, they stand out in relief above the surface with an appearance of having been sprinkled from a pepper pot.[1]

[1] *Op. cit.* p.543–44.

While these differences are by no means so obvious as those which serve to separate the basal beds from the remainder of the formation, they are sufficiently distinct to enable one to recognize the horizon dealt with in good exposures, provided the extension of van Ingen's work over a larger area shows them to be persistent. The writer's work in the district has been mainly that of hurried areal mapping, and is not therefore of sufficiently detailed character to enable him to express an opinion of any value on this work of van Ingen's, though, so far as it goes, he is disposed to coincide. Precisely the same differences which van Ingen notes have been observed, but the work was not done in sufficient detail to warrant publication. In addition it may be stated that frequent pebbly beds occur throughout the formation, in which the pebbles are almost exclusively of white quartz, with a tendency to concentration on the upper surfaces of layers which are otherwise of pure sand, instead of being disseminated through the layer. Such pebbly horizons seem much more characteristic of the middle division than of the upper.

The thickness of the Potsdam in Clinton county is unknown. The thickest measured section is that in the Ausable chasm, but the section there is complicated by faulting and is by no means complete, all the basal portion being lacking. Walcott's measurement gives 350 feet, and van Ingen's "at least 455 feet" as the thickness here. In the Morrisonville well, with the drill resting at 1250 feet in the Potsdam sandstone, at least 750 feet of the formation had been drilled through, and the bottom samples were of clear, glassy quartz sand, with no trace of the feldspars which characterize the basal portion, indicating that it had not been reached.[1] From this record alone it seems perfectly safe to say that the formation has a thickness considerably in excess of that amount in Clinton county. The writer's estimate, based on the broad belt of outcrop in the northern part of the county, assigns a minimum thickness of at least 1,000 feet to the formation, with a likelihood that it is considerably in excess of that amount.

[1] 19th An. Rep't State Geol. p.r69.

Van Ingen's study of the Saranac river section of the Potsdam, extending along the river for 2 miles above and below Cadyville, leads him to compute the thickness there shown at 1150 feet.[1] The writer agrees with him that there is no evidence of faulting in this section, though he believes that it is terminated by a fault at each end. Certainly one of the biggest faults in the district, the Tracy brook fault, crosses the river somewhere between the lower end of the section and Morrisonville, though apparently with much diminished throw hereabouts. The Potsdam is a most difficult formation on which to get accurate dip measurements, and the writer's notes give the dip as somewhat less than that stated by van Ingen, averaging about 5° instead of between 5° and 10°, as given by him, which would cut down the above thickness by some 300 feet. Whichever result be the more correct, the thickness is impressive, since the basal beds do not show, nor is the summit reached. Basal beds do indeed occur in the near vicinity, showing in frequent outcrop on the higher ground a mile south of Cadyville. These are on the strike of the river exposures and at a higher altitude, yet belong much below them stratigraphically, and the writer is disposed to the conclusion that a fault intervenes between the two, likely a branch from the Tracy brook fault. These beds show considerable thickness, and it is thought highly probable that the thickness of the whole Potsdam is more likely over, rather than under 1500 feet.

The paleontologic and stratigraphic work of Walcott and van Ingen has shown that the upper portion of the formation, through a thickness of some 350 feet, carries a sparse Upper Cambric fauna. With the exception of a few supposed tracks, of uncertain nature, no fossils have so far been found in all the remainder of the formation, and there is therefore an utter lack of paleontologic evidence as to its age, and the possibility that the lower portion may be older than the Upper Cambric must be conceded. But it seems to the writer that, fossil evidence being lacking, the formation as it occurs in New York is not susceptible of subdivision. The basal rocks grade into those of the middle division, as do those into the upper, and there is no marked structural break at any horizon which would warrant the assumption of any great difference in age between base and

[1] *Op. cit.* p.532.

summit, or any marked pause in sedimentation. Prof. N. H. Winchell has long held, and has recently reiterated the view, that the typical Potsdam at Potsdam is much older than the upper, white, less indurated beds, and he classes it in the middle Cambric and correlates it with a portion of the Keweenawan of the upper lake region.[1] As above indicated, the writer's judgment is that any present attempt to divide the formation on the basis of age is premature and has but slender basis of fact, considering the lack of all evidence from fossils.

As has been shown by many observers, the transition from Potsdam to Beekmantown sedimentation is not a sharp one but through a series of passage beds. Near the summit of the former, thin beds of gray dolomite make their appearance, interbanded with the soft, white sandstones which prevail there, increase in frequency till they constitute half the mass of the rock, and finally prevail and cut out the sandstones altogether. The sandstone layers are characteristically Potsdam in appearance, and the dolomites as characteristically Beekmantown. There is no mixing of materials but rather a rapid alternation of two contrasted sets of deposition conditions. Walcott has measured a thickness of 25 feet of such passage beds along the Chateaugay river and 70 feet near Whitehall. In the writer's judgment, the latter is much nearer the usual figure than the former. These beds are exposed at many localities along the northern border of the region, but seldom suitably for measurement of thickness. They seem usually of considerable bulk.

Beekmantown (Calciferous) formation. Just as in the case of the Potsdam beneath, the Beekmantown formation is thickest on the northeast margin of the Adirondack region and thins out to the west and south, though the thinning is less rapid, so that the formation extends much beyond the limits of the Potsdam, being lacking only on the west side of the region. The type locality is at Beekmantown, Clinton co., where the formation is very fossiliferous, but where the section is quite incomplete; in fact, there is no one locality in Clinton county where anything like a complete section of the formation can be obtained.

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[1]Am. Geol. April 1903, p.246–49.

For such sections recourse must be had to the district nearer the upper end of the lake. Here the dips are steeper, and there are two localities in Shoreham Vt, where the full section is shown, and the section about Fort Ticonderoga is quite complete also. These sections have been studied in detail by Brainard and Seeley, and the results obtained there applied to other parts of the Champlain region.[1] No other work approaching this for detail and accuracy has been done on the formation in the Champlain region. In their type section at Shoreham they have recognized five subdivisions of the formation, as follows:[2]

Feet

A Dark iron-gray magnesian limestone, usually in beds 1 or 2 feet in thickness, more or less silicious, in some beds even approaching a sandstone. Nodules of white quartz are frequently seen in the upper layers, and near the top large irregular masses of impure black chert, which, when the calcareous matter is dissolved out by long exposure, often appears fibrous or scoriaceous. Thickness................ 310

B Dove-colored limestone, intermingled with light gray dolomite in massive beds; sometimes for a thickness of 12 or 15 feet no planes of stratification are discernible. In the lower beds, and in those just above the middle, the dolomite predominates; the middle and upper beds are nearly pure limestone; other beds show on their weathered surfaces, raised reticulating lines of gray dolomite. Thickness........ 295

C, 1 Gray, thin bedded, fine grained, calciferous sandstone, on the edges often weathering in fine lines, 40 or 50 to the inch, and resembling close grained wood. Weathered fragments are frequently riddled with small holes, called Scolithus minutus by Mr. Wing... 60

2 Magnesian limestone in thick beds, weathering drab 100

3 Sandstone, sometimes pure and firm, but usually calciferous or dolomitic.............................. 70

4 Magnesian limestone like no. 2, frequently containing patches of black chert.............................. 120

Thickness of C.................................. 350

[1] Am. Mus. Nat. Hist. Bul. 3:1–23.

[2] *Op. cit.* p.2–3.

	Feet
D, 1 Blue limestone in beds 1 or 2 feet thick, breaking with a flinty fracture, often with considerable dolomitic matter intermixed, giving the weathered surface a rough, curdled appearance; becoming more and more interstratified with calciferous sandstone in thin layers, which frequently weathers to a friable, ocherous rotten stone....	80
2 Drab and brown magnesian limestone, containing also toward the middle several beds of tough sandstone..	75
3 Sandy limestone in thin beds, weathering on the edges in horizontal ridges one or two inches apart, giving to the escarpments a peculiar, banded appearance. A few thin beds of pure limestone are interstratified with the silicious limestone..	120
4 Blue limestone in thin beds, separated from each other by very thin, tough slaty layers, which protrude on the weathered edges in undulating lines. The limestone often appears to be a conglomerate, the small inclosed pebbles being somewhat angular and arenaceous........	100
Thickness of D..	375
E Fine grained, magnesian limestone in beds 1 or 2 feet in thickness, weathering drab, yellowish or brown. Occasionally pure limestone layers occur, which are fossiliferous, and rarely thin layers of slate. Thickness..........	470
Total thickness..	1800

Cassin formation. In the upper part of division D and in division E are numerous fossiliferous horizons carrying a rather abundant fauna. These beds are confined to the Champlain valley so far as the immediate region is concerned, and have therefore the same restricted distribution as the following Chazy. In discussing Brainard and Seeley's paper, Professor Whitfield recognizes and emphasizes this point and the considerable differences between these upper beds and the ordinary, sparingly fossiliferous character of the normal Beekmantown. He urges the similarity of the fauna to that of the Quebec group of Canada, argues that these beds have more natural affinity with the Chazy than with the

Beekmantown, and that they should either be placed with that formation or else considered as distinct from either and given a separate name, "as Fort Cassin, or Philipsburg formation, or any other appropriate name."[1] This seems to the writer not only an eminently proper, but really a necessary procedure. The thickness and importance of this group, consisting of the upper 220 feet of division D and the whole of E, is such as definitely to warrant its separate mapping in the Champlain region, and the writer proposes the name "Cassin formation" for it, to make Whitfield's suggestion more precise and definite. The question as to whether the rocks involved are to be classed with the Chazy or with the Beekmantown, or with neither, is not at issue in the giving of the name, the point made being simply that we have here several hundred feet of limestone of definite lithologic and paleontologic character, whose definiteness and importance would seem to warrant its separate recognition and mapping as a substage. In the type section, at Beekmantown, the rocks of this upper horizon are not exposed. The matter will be reverted to on a subsequent page in considering the subdivisions of the Chazy limestone.

When the Beekmantown formation is followed to the south and around into the Mohawk valley, it is found to be much thinner than in the Champlain region, and the upper portion, that which has been separated above as the Cassin formation, is wholly wanting. Prosser has carefully measured a number of sections in this region, but measurements of the full thickness can rarely be made because the formation is seldom cut through to its base, and because it overlaps on the Precambric, thus not presenting its full thickness close to the Precambric border. At Little Falls the formation is 456 feet thick. The deep wells at Ilion and Utica, a few miles farther west and at a somewhat greater distance from the Precambric edge, show a somewhat, but not greatly increased thickness. Eastward from Little Falls the sections in the valley do not get down to the base of the formation, except at Spraker, where Prosser measured a thickness of 500 feet, with the summit not exposed, but the thickness does not vary greatly apparently, though showing some diminution east of

[1] Am. Mus. Nat. Hist. Bul. 3:27–28.

Spraker. The upper beds contain Ophileta and seem of about the same age as the basal part of division D of Brainard and Seeley's section. The upper Cassin beds are wholly lacking in the Mohawk valley, and apparently the latter region was uplifted while they were being deposited on the east. Certainly, the connection between the two areas was broken during this time, confining the Cassin fauna to the Champlain basin, and this seems to the writer an added reason for the separation of the Cassin beds from the normal Beekmantown.

On the north side of the Adirondacks the exposures of the formation are poor and infrequent, the dips are flat, and the breadth of outcrop considerable, with the full thickness not showing on the New York side of the international boundary. Nothing definite is known concerning the thickness in this area, but, as its western limits are reached, in the Thousand islands region, it becomes evident that the formation has greatly thinned. On the western side of the region it is wholly absent, the later Black River and Trenton limestones resting directly on the Precambric, making it perfectly evident that the Beekmantown shore line there lay farther to the west than the present Precambric boundary. Moreover, the imperfect records of the gas wells of Oswego and Jefferson counties, as given by Orton, indicate a thickness of only 200 feet of Beekmantown rocks under cover in the former county, and none at all in the latter, the former wells being 35 miles, and the latter 15 miles distant from the present Precambric boundary.[1] It seems therefore that the Beekmantown sea covered by no means all of the present Precambric region of northern New York, and that the main area left unsubmerged by its waters was on the west and south. On the west the shore was several miles west of the present Precambric edge; on the south it did not extend in more than from 10 to 30 miles beyond the present edge, as the writer has elsewhere shown;[2] much less is known about the rate of overlap on the northeast, but the great thickness of both the Potsdam and Beekmantown formations there would indicate that, by the close of the Beekmantown, the sea must have widely encroached on that portion of the region.

[1] N. Y. State Mus. Bul. 30, p.442, 458.
[2] N. Y. State Mus. Bul. p.77.

Chazy formation. The Chazy rocks are found, at the present day, only on the eastern border of the Adirondack region. Their present distribution gives but little idea of the extent of the sea in which they were deposited, which must have encroached widely over the present northeastern portion of the Adirondacks, from which the deposits have been since removed by erosion. But the formation is wholly lacking on the remaining sides of the region, and can not have been laid down there at all. On the contrary, the Beekmantown land area of the southern and western parts of the region became greatly extended in those directions, shutting out the sea altogether, and leaving merely the eastern area submerged during this time.

Much detailed study has been given the Chazy formation throughout the Champlain valley by Brainard and Seeley.[1] For stratigraphic detail and accuracy this work can not be improved on. It shows that the formation is thickest in the latitude of southern Clinton county; that it rapidly thins southward to utter disappearance at the upper end of Lake Champlain; and that it also thins northward and moreover changes considerably in character in this direction.

Throughout most of the Champlain valley the formation consists essentially of beds of quite pure, clear water limestones, with a surprisingly small amount of land wash of any sort, in itself an indication of considerable width for the basin, much beyond what the present breadth of outcrop would indicate. The formation is thickest on Valcour island, and Brainard and Seeley's measured section there is here reproduced.

Group A (Lower Chazy)

		Feet
1	Gray or drab sandstone, interstratified with thin (or sometimes thick) layers of slate, and with occasional thin layers of limestone at the base, containing *Camerella (?) costata* Bill........................	56
2	The slaty sandstone gradually passes into massive beds, made up of thin alternating layers of tough slate and nodular limestone, containing undetermined species of Orthis and Orthoceras............................	82

[1] Am. Geol. 2:323–30; Geol. Soc. Am. Bul. 2:293–300; Am. Mus. Nat. Hist. Bul. 8:305–15.

		Feet
3	Dark bluish gray, somewhat impure limestone, in beds of variable thickness; often packed with Orthis costalis Hall, which occurs with more or less frequency through the whole mass. Other fossils are: Lingula huronensis Bill., Harpes antiquatus Bill., H. ottawaensis Bill.(?), Illaenus arcturus Hall, (I bayfieldi Bill.), Lituites sp.(?)...	110
4	Gray, tolerably pure limestone in beds 8 to 20 inches thick, separated by earthy seams, the bedding being uneven. Many layers consist of crinoidal fragments, largely of Paleocystites tenuiradiatus Hall. Near the middle of the mass for a thickness of 10 feet, some of the fragments and small, ovoid masses (Bolboporites americanus Bill.) are of a bright red color.	90
	Making for the total thickness of A...............	338

Group B (Middle Chazy)

1	Impure, nodular limestone containing Maclurea magna Les................................	25
2	Gray, massive, pure limestone, abounding in crinoidal fragments	20
3	Bluish black, thick bedded limestone, usually weathering so as to show pure nodular masses enveloped in a somewhat impure lighter colored matrix; everywhere characterized by Maclurea magna. Near the middle of this mass for a thickness of about 30 feet, the fossils are silicified and of jet-black color. The more important besides Maclurea, are species of Strophomena, Orthis and Orthoceras.........................	210
4	Dark, compact, fine grained limestone, with obscure bedding, weathering to a light gray. Fossils are infrequent, but at a single locality were collected Orthis perveta Con., O. platys Bill., Leptaena fasciata Hall, Asaphus canalis Con., Cheirurus polydorus Bill., Harpes sp. und., Illaenus incertus Bill., Lichas minganensis Bill., Sphaerexochus parvus Bill., and several undescribed species..................	20

		Feet
5	Bluish black limestone like no. 3, but less pure, containing Maclurea magna Les., Orthis perveta Con., Strophomena incrassata Hall, Orthis disparilis Con., or O. porcia Bill	75
	Total thickness of B	350

Group C (Upper Chazy)

1	Dove-colored, compact limestone, in massive beds, containing a large species of Orthoceras, Placoparia (Calymmene) multicosta Hall, Solenopora compacta, and a large Bucania	60
2	Dark impure limestone, in thin beds, abounding in Rhynchonella plena; at the base a bed 4 or 5 feet thick is filled with various forms of Monticulipora or Stenopora	125
3	Tough, arenaceous magnesian limestone, passing into fine grained sandstone	17
	Total thickness of C	202
	Aggregate thickness of the Chazy on Valcour island	890

In the same papers the authors show that the diminution in thickness of the formation southward is brought about by disappearance of the lower and upper divisions, so that in the more southerly exposures, only the middle division remains, and that this then rapidly pinches out to disappearance. To the northward the work of the Canadian geologists has shown that the formation rapidly changes in character in that direction, land wash entering much more prominently into its make-up than is the case along Lake Champlain.

It is thus seen that the Chazy is a comparatively local formation, laid down in an arm of the sea which occupied the present line of the Champlain valley, whose upper end limited its waters on the south. Its breadth however, specially on the New York side, was much greater than the present limits of the outcrops would indicate. The southern end of the basin was depressed for a much shorter time than the central portion, and its deposits

are of the middle division. While the Chazy was being deposited, the remainder of the State seems to have been mostly above sea level, and either the same conditions obtained during Cassin deposition or else a barrier was developed between the Champlain and Mohawk basins at this time, preventing the Cassin fauna from reaching the latter area. While the writer is not a sufficiently competent paleontologist to appreciate or discuss the relationships or differences of the Cassin and Chazy faunas, it does seem to him that structurally the Cassin is related to the Chazy rather than to the Beekmantown. The uplift which shut off this basin from the waters of the remainder of the State, and then caused those waters to recede beyond the State's boundaries, took place prior to Cassin deposition, and these conditions persisted during the Chazy, followed by an uplift and then by the great depression which let in the waters of the Black River and Trenton seas over the whole region. It is true that in the Champlain region there is no natural lithologic boundary between the Beekmantown and Cassin, while the basal sandstone of the Chazy does indicate a physical change. But this is a slight one and not to be compared to the greater ones outlined above.

Day Point, Crown Point and Valcour substages. The three divisions of the Chazy are sharply marked off from one another lithologically and seem to the writer equally so paleontologically. Moreover, their thickness and importance over most of the Champlain region seem to warrant their separation in mapping, a matter easy of accomplishment on the scale of the 1 inch maps. They would seem therefore worthy of separate names. Brainard and Seeley's lines of division can not be improved on, as it seems to the writer, and the following names are suggested for them; for division A the Day Point limestone; for B the Crown Point limestone; and for C the Valcour limestone. These are not intended to replace the group name but simply as indicative of the three well marked substages of the group. Division A is well shown along the lake shore in the northern part of Peru township, is exceedingly fossiliferous there, and in the near vicinity both contacts are to be found, the upper at Bluff point, the lower on

Valcour. The lower part of division B is magnificently shown on Bluff point, in the southern part of Plattsburg township, and the full thickness, except for occasional small gaps, is well exposed in the Chazy wedge between the Beekmantown and Plattsburg faults in the northern portion of the town.[1] Both contacts show here, and large quarries are opened in the rock. The upper division is splendidly shown on Valcour island, with exhibition of both contacts. It is perhaps equally well shown in Chazy township, and the middle division is also well displayed there with full thickness; but, since the name is used for the full formation, it can not be applied to a substage.

Lowville (Birdseye) limestone. In the Mohawk valley the Beekmantown rocks are in many places capped by the thin limestone formation to which the above name has been given. The rock is mostly a gray to drab, brittle, quite pure limestone, usually in rather large massive layers from 1 to 4 feet thick. though much of it is thinner bedded also. It is everywhere penetrated with the vertical, branching tubes of the fucoids which are so characteristic of the formation, which are usually filled with crystalline calcite, and whose cross sections on many surfaces give rise to the bird's-eye appearance which gave the original name to the formation.

Its distribution is erratic and is a matter of considerable importance. It is limited to the south and west sides of the Adirondacks, in the former situation resting on the Beekmantown, and in the latter apparently on the Precambric, though no actual contact is exposed in the whole region, so far as the writer is aware. The drift is very heavy in that region, and little or no work has been done on the rocks since the reports of Emmons and Vanuxem were published. Apparently the formation extends through Herkimer, Oneida, Lewis and Jefferson counties and in considerable strength, but with its base nowhere showing. Toward the north, in Jefferson, the Beekmantown and Potsdam formations begin to appear thinly underneath. Emmons reports a thickness of 30 feet near Watertown, which is probably simply an estimate. This whole western contact line is in need of careful study.

[1] 15th An. Rep't State Geol., p.556.

Returning to the south side, Prosser's sections through the Mohawk valley,[1] together with the supplementary ones of the writer about Little Falls, are sufficient to show well the bulk and distribution of the formation there. Along East and West Canada creeks the thickness is between 20 feet and 25 feet, beneath which, in most places, there is a gradation into the Beekmantown below through a series of passage beds of intermediate composition and appearance, which have about the same thickness as the Lowville itself. In the district between the two creeks the formation has the same general character though locally the passage beds are lacking and the formation thins. At Canajoharie, 17 miles down the river from Little Falls, the Lowville is absent, the unconformity at that horizon being more plainly marked here than at any other locality. Three miles beyond, about Spraker, the conditions are the same. At Tribes Hill, halfway between Fonda and Amsterdam, and 13 miles below Spraker, the Lowville has reappeared, though no complete section of it has been published, and the passage beds at the base are lacking. About Amsterdam and Hoffman the formation is usually present but very thin, not exceeding 8 feet, seldom reaching 5, and often falling to 2 feet, showing much variation over short intervals and sharply separated from the Beekmantown. East and northeast from this point it is usually absent though occasionally seen, and the last reported occurrence seems to be that near Saratoga, where the thickness is but 2 feet. In this neighborhood the Beekmantown is also very thin, apparently marking the place where the rising of the land during Beekmantown times was first felt, and where the separation of the Champlain and Mohawk Beekmantown basins was first effected.

The prominent features brought out by these sections are: the resting of the Lowville on the Precambric along the western side of the region, the conspicuous unconformity at Canajoharie, the passage beds to the Beekmantown in the West Canada creek region and the great irregularity of the formation eastward from there, with its final disappearance about Saratoga. It is as plainly confined to the south and west sides of the region as the Chazy and Cassin are to the east side; and was thus deposited in

[1] 15th An. Rep't State Geol. p.619–59, and N. Y. State Mus. Bul. 34.

a wholly different basin. On the west its waters encroached farther on the Precambric land than the Beekmantown waters did. On the south it was very irregularly deposited, owing to slight unevenness of the floor. It is not certain whether it was contemporaneous with the later Chazy or followed that in time. Its fluctuations in thickness, its occasional absence, and its sharp contact line with the Beekmantown through most of the Mohawk valley give physical evidence of a considerable time gap between the two formations, during which some slight flexing and erosion of the Beekmantown rocks took place, and during which the Cassin and Chazy rocks were being deposited in the Chazy basin. This evidence is so clear that it would seem that the apparent passage beds in the West Canada creek district can not be actually such, but belong with the Lowville. The Lowville depression seems to have invaded the district from the southwest, and these beds represent an older stage of the formation than do any of those found to the eastward in the Mohawk valley.

Black River limestone. This formation is found on all sides of the Adirondacks, though locally lacking in the Mohawk valley. Throughout the Champlain valley region it shows a massive, basal layer of pure, dove-colored limestone which much resembles the Lowville except that it lacks the characteristic calcite tubes. Above this layer the entire formation consists of massive layers of solid, brittle, pure, black limestone, breaking with conchoidal fracture. About the lower end of Lake Champlain it ranges from 30 feet to 50 feet in thickness. Southward along the lake the writer has not seen the sections, but White reports a measured thickness of 71 feet, 3 inches on Crown Point peninsula, the greatest observed thickness reached in the State.[1] From this point it thins toward the south, as do all the Paleozoic formations of the region. In Saratoga county it has an intermediate character, containing layers which resemble the Lowville, Prosser's sections at Glens Falls showing a thickness of 27 feet for the two combined. This seems however an exceptional thickness, most sections in the vicinity being vastly thinner. Coming around into the Mohawk valley, the formation ranges from 5 to 9 feet in thickness about Amster-

[1] White, T. G. Geol. Soc. Am. Bul. 10:457.

dam and Hoffman, as Prosser has shown, and is in part massive, in part thin bedded and lumpy. At Tribes Hill there is a 3 foot lumpy layer between the Lowville and Trenton which he refers doubtfully to the Black River. At Canajoharie and Spraker the Black River is absent, as is the Lowville, flat Trenton beds lying directly on slightly folded Beekmantown. In the district about Little Falls it is sometimes present, but more frequently absent, varying rapidly within short distances. Thus at Ingham Mills Prosser gives two sections, which the writer has also seen, in one of which there are 5 feet of black, lumpy limestone, capped by an 18 inch stratum which is lithologically like the Lowville beneath. Near at hand, in the second section, the succession is the same, but the Black River is only 2 feet thick, though it is followed by the same recurrent Lowville layer, above which the Trenton appears. At the old kiln, ¼ mile to the north, is a still better section, showing 8 feet of fossiliferous Black River limestone, underlain by a thickness of 10 feet of Lowville beds, and capped by the Trenton [pl.4]. As in all cases hereabout, the rock is quite thin bedded and lumpy with shale partings. Northward from Little Falls the formation is seldom present and then is very thin; the same is true in the many sections about Middleville. About Newport it has reappeared, with a thickness of 5 feet to 6 feet, thin bedded and lumpy as at Ingham Mills. Followed northwest from here it thickens, and becomes persistent and massive. T. G. White reports a thickness of 20 feet at Boonville and Lyons Falls, respectively 25 miles and 35 miles northwest of Newport, in the Black river valley.[1] It is here for the most part quite massive, though somewhat shaly in its upper portion.

Farther to the northward, there is little or no accurate published information concerning the formation. Emmons gives the thickness at Watertown as from 7 feet to 8 feet, and the rock somewhat lumpy, though without shaly partings.[2] All along this side of the region the glacial deposits are exceedingly heavy, making rock outcrops very exceptional and meager. There seems however, no reason to doubt that the Black River

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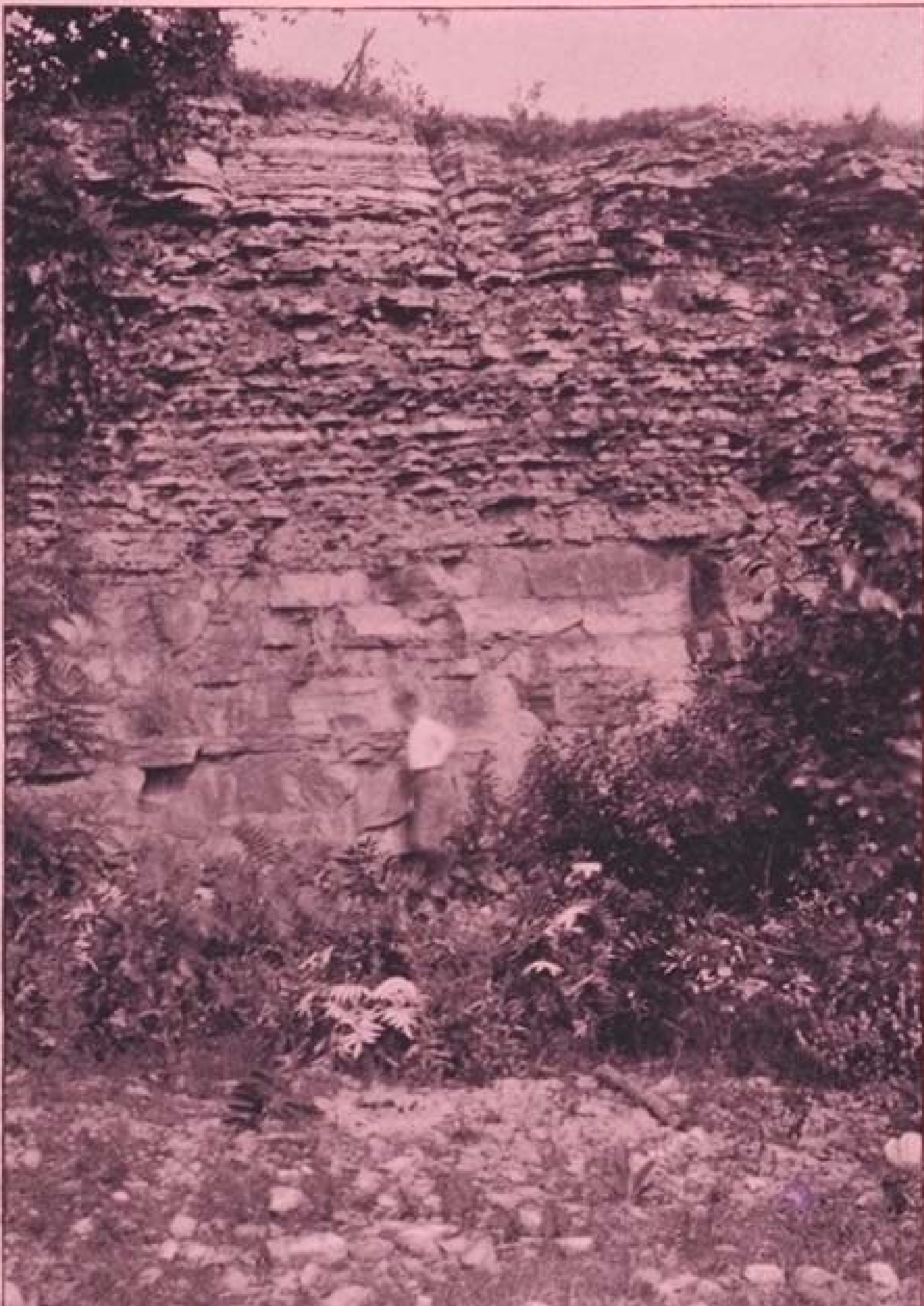
[2] N. Y. State Mus. 51st Rep't, 1: r27–29.
[2] Geol. N. Y. 2d Dist. p.386.

Plate 4



Quarry face at bridge north of Ingham's Mills, showing 10 feet of Lowville (Birdseye) limestone at base, followed by 8 feet of thin black limestone bands with shale partings, of Black river age, and capped by 5 feet of Trenton limestone

extends along it unbroken, with the Lowville beneath. Hence the Black River sea surrounded the region on all three sides with apparently unbroken connections, much diminishing the size of the former land areas of the region, even that of Beekmantown times, which was the smallest of those that preceded it. The present outcrops of the Mohawk valley are near the old shore line, and the irregular, ridgy character of the bottom was the cause of the variations in thickness of the formation there. Had erosion cut somewhat deeper, in other words, were the exposures of the formation on a line somewhat south of the present, it would undoubtedly extend east and west unbroken. The Beekmantown pebbles in the Black River, in the Tribes Hill-Amsterdam region, reported by Vanuxem and by Prosser, are very significant as showing the near vicinity of the shore line.[1]

Trenton formation. The Trenton formation may be said to show a general uniformity in lithologic character all about the Adirondack region, though with much variation in detail from place to place. Instead of the quite pure, massive limestones of the Chazy and Lowville formations, the major portion of the Trenton is found to consist of thin bedded, black, shaly limestones, often with partings of black, calcareous shales, the entire formation being thus contaminated with a certain amount of land wash in the shape of fine mud. The limestones are usually hard and brittle, with conchoidal fracture, though becoming thin bedded and shaly, and even the heavier beds split thinly on weathering.

In all sections there is considerable gray, rather coarsely crystalline, fairly pure, very fossiliferous limestone, usually thin bedded though sometimes becoming fairly massive. While sometimes fairly persistent for considerable distances, such beds are usually lens-shaped masses of restricted lateral extent, entirely surrounded by the black calcareous muds of the ordinary character. Beds of this sort seem less local and more persistent in the Mohawk than in the Champlain valley, as has been pointed out by White, and constitute a larger portion of the formation in the former situation, indicating less local variation in the

[1] Geol. N. Y. 3d Dist. p.44; 15th An. Rep't State Geol. 1:653.

conditions there.[1] In the Champlain valley they are more limited to the basal portion of the formation than is the case along the Mohawk.

In the lower Champlain region the writer knows of no continuous section of the Trenton, and its thickness there is largely a matter of conjecture. A minimum limit may be assigned, but no maximum, and there are beds, apparently Trenton, whose stratigraphic horizon is yet unknown. In the bed of the Little Chazy river, at Chazy village, the lower 150 feet of the formation are shown, directly overlying the Black River beds, and consisting at the base of slaty layers, alternating with beds of hard, brittle, blue black limestone; the major portion of the section being however constituted of the limestone, the slaty layers vanishing, and in this portion are occasional layers of the gray, crystalline limestone which are masses of fossils.

Along the lake shore northward from Bluff point, Trenton rocks outcrop continuously for ⅓ mile, being separated from the Chazy limestones which constitute the point by a fault. Because the outcrop surface is horizontal, and the dip varies much in amount and direction, it is a difficult section to measure accurately, but a thickness of at least 100 feet is involved. At the base are many of the coarse gray, fossiliferous layers, but these die out toward the summit, and the rock becomes shaly. This section seems to overlap, in part, the section at Chazy, but to show higher beds than any seen there.

On Crab island, a mile northeast from Bluff point, out in the lake, an excellent Trenton section is exposed which is practically a continuous one. The exposures comprise part of a low, northerly pitching anticline, the island is nearly a half mile long, and the writer has estimated the thickness of the section at 200 feet. Brainard and Seeley state the thickness to be over 200 feet, and the writer is confident that White's figure of less than 100 feet falls far short of the truth.[2] The lower part of the section, at the south end of the island, shows much of the gray, crystalline, fossiliferous limestone. Following this are thin bedded, slaty layers, but the upper part of the section, comprising more than

[1] Geol. Soc. Am. Bul. 10:455.

[2] Cushing, H. P. 15th An. Rep't State Geol. p.514; Brainard & Seeley. Am. Mus. Nat. Hist. Bul. 8:308; White, T. G. Geol. Soc. Am. Bul. 10:457.

Plate 5

Black marble and overlying thin bedded limestone in a quarry on the north side of the Hudson river at Glens Falls

half of its thickness, is formed of blue black, brittle, somewhat muddy limestones, carrying a trilobite, cephalopod, lamellibranch fauna, as distinguished from the abundant brachiopod fauna of the gray limestone. These rocks are nearly on the strike of the section north of Bluff point, and there is unquestionably some overlap in the two; but, as the larger part of the Crab island section is of higher beds than any shown in the other, these three sections can only be fitted together by the most painstaking paleontologic work, perhaps not even by that. The writer is confident that the upper beds on Crab island are from 300 feet to 350 feet above the base of the formation. These are the three best sections of the Trenton which the writer has seen toward the lower end of the lake. They indicate a large thickness for the formation, but give no clue to the amount that may be lacking above the upper beds of the Crab island section.

In a recent report on the geology of Grand isle, Vermont, Professor Perkins has described an interesting section which shows that there is no sharp, lithologic break between the limestones of the Trenton and the overlying black shales of Utica age, but rather an imperceptible gradation from the one into the other, forming a series of passage beds.[1] These consist of rapidly alternating shales and limestones, with a comparatively steady increase upward in amount of shaly matter. The thickness of these beds is not stated, possibly because the section is not sufficiently complete, possibly because their recognition as a separate lithologic unit simply increases the difficulty of constituting boundaries by making two vague horizons instead of one. The beds of distinctively intermediate character seem however to be of considerable thickness.

Along the shores of Cumberland head, on the New York side of the lake, is an excellent, though much disturbed, section, consisting of blue black slaty limestones and calcareous shales, with some firmer limestone bands. These rocks are much faulted and squeezed, and somewhat folded, with much development of slaty cleavage at a high angle with the bedding planes. These rocks extend along shore northward to beyond Point au Roche, in Beekmantown. Dr White states that similar rocks occur on

[1] Rep't Vt. State Geol. 1901–2, p.167–68.

Grand isle, directly opposite Cumberland head, and it would seem that these are the rocks referred to as transition beds by Professor Perkins.[1] From the study of the fauna White seems to be somewhat uncertain as to the precise horizon, and speaks of it as "very high Trenton or Utica".[2] Since the passage beds on Grand isle are demonstrably such, a comparison of their faunas with those of the Cumberland head rocks should settle the question of stratigraphic equivalency. But, if these be actually the passage beds, their thickness is apparently large, though the Cumberland head section is so greatly disturbed that little exact idea as to its thickness can be obtained. The lithologic character would seem to agree with such a reference.

Published data of precise character in regard to the thickness and nature of the Trenton toward the upper end of the lake, are not numerous. On the Vermont shore, across the lake from Port Henry, Brainard and Seeley give a measured thickness of 314 feet for the Trenton, the exposures being a continuation of the section on Crown point, on the New York side.[3] It is in this section that the Black River limestone attains its maximum thickness of 71 feet. White says of it that, on Crown point, above the Black River, is a continuous series of 100 feet of alternating, compact, sandy and shaly layers, all quite thin, containing the lower and middle Trenton fauna of the region.[4] It is not clear from their account, whether Brainard and Seeley include the Black River in their statement of the thickness of the Trenton or not. White states that there is a hiatus between the upper Trenton bed exposed and the Utica outcrops beyond, but makes no statement in respect to its amount. Nothing is therefore apparent as to the transition beds in the region. But, unless a fault intervenes, it would seem that they can not be of very considerable thickness.

At Larrabee point, opposite Fort Ticonderoga, White gives the Trenton a thickness of 110 feet, the section terminating in that formation, though Utica shale appears in place not far away.[5] The lithologic character of the formation is not touched on, and we

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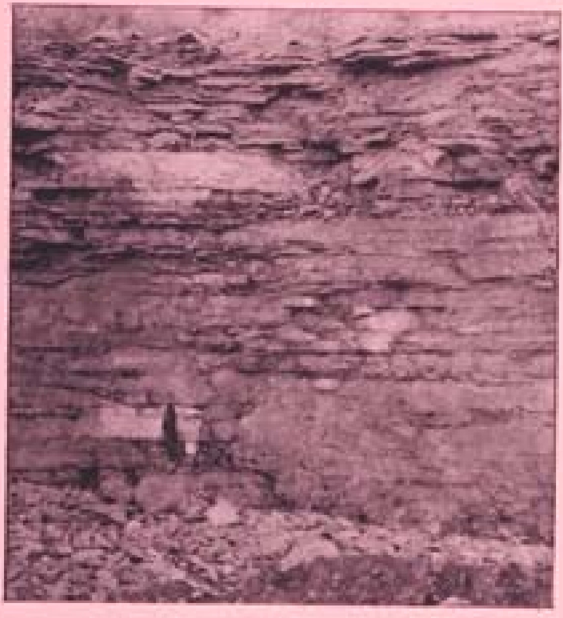
[1] *Op. cit.* p.114.
[2] *Op. cit.* p.460.
[3] Am. Mus. Nat. Hist. Bul. 8:313.
[4] Geol. Soc. Am. Bul. 10:457.
[5] *Op. cit.* p.456.

Plate 6



Trenton limestone in a quarry at Howland's Mill, Saratoga co.

are left in doubt as to how large a portion is shown, and whether or not a fault intervenes between the Trenton and Utica, as is very likely. Faults so abound in the Champlain region that the finding and measurement of complete sections is a matter of great difficulty, so abound in fact that the geologist is more often called on to demonstrate their absence than their presence. If there is none here, the Trenton has obviously thinned greatly southward.

In the country between Lake Champlain and the mouth of the Mohawk, exposures of the formation are interrupted and fragmentary. At Glens Falls Prosser has measured several Trenton sections, but all terminate in that formation, so that the full thickness is not shown.[1] The greatest measured thickness in the vicinity is 63 feet, the basal portion consisting of very massive, black, fine grained beds, while above is much thinner bedded material, with some intercalation of gray, crystalline layers. If the total thickness were much greater than that shown in this section, it would seem that thicker sections would surely be forthcoming, and their nonappearance seems therefore significant. No passage beds seem to have been noted, but whether their absence is due to nonexposure of the proper horizon or not, is not clear.

Similarly, about Saratoga, Prosser's sections show a maximum measured thickness of 37½ feet for the Trenton, mostly thin bedded, but some massive, and here again the summit is not exposed, so that the entire thickness may be in excess of that amount, but is not likely to be greatly in excess [pl.6].

While the sections at these two localities are not decisive as to thickness, it seems probable that the entire amount can not greatly exceed the figures given, and hence that the formation has rapidly thinned in this direction.

In the lower Mohawk valley, in the Amsterdam-Hoffman region, Prosser and Cuming's sections afford accurate data concerning the formation.[2] They show considerable variation in thickness, the maximum amount being 36½ feet in the section at Morphy's, while the minimum is 20 feet. The lower 6 to 8 feet are of massive, often crystalline, limestone, while the remainder consists of thinner bedded and dark colored, more shaly material.

[1] N. Y. State Mus. Bul. 34, p.480–82, pl.8.

[2] 15th An. Rep't State Geol. p.647–59; N. Y. State Mus. Bul. 34, p. 419–64.

Coming westward, at Tribes Hill, a measured 40 feet of Trenton is the section record, and it terminates in the formation, so that the actual thickness may be somewhat greater. At the base is a 12 foot thickness of massive, dark blue limestone, with some crystalline lenses, followed by 11 feet of thin bedded, uneven, gray crystalline and dark colored limestones, which are capped by 17 feet of thin bedded, uneven, dark blue limestone.

At Spraker the formation has thinned to 17 feet, both contacts showing, and consists of thin layers of dark blue limestone, apparently representing the upper part only of the Tribes Hill section and with the Lowville and Black River both lacking as well. Three miles west, at Canajoharie, the thickness and lithologic character are the same, and here the unconformity between the Beekmantown and Trenton is also plainly marked by a discordance in dip [pl.7].

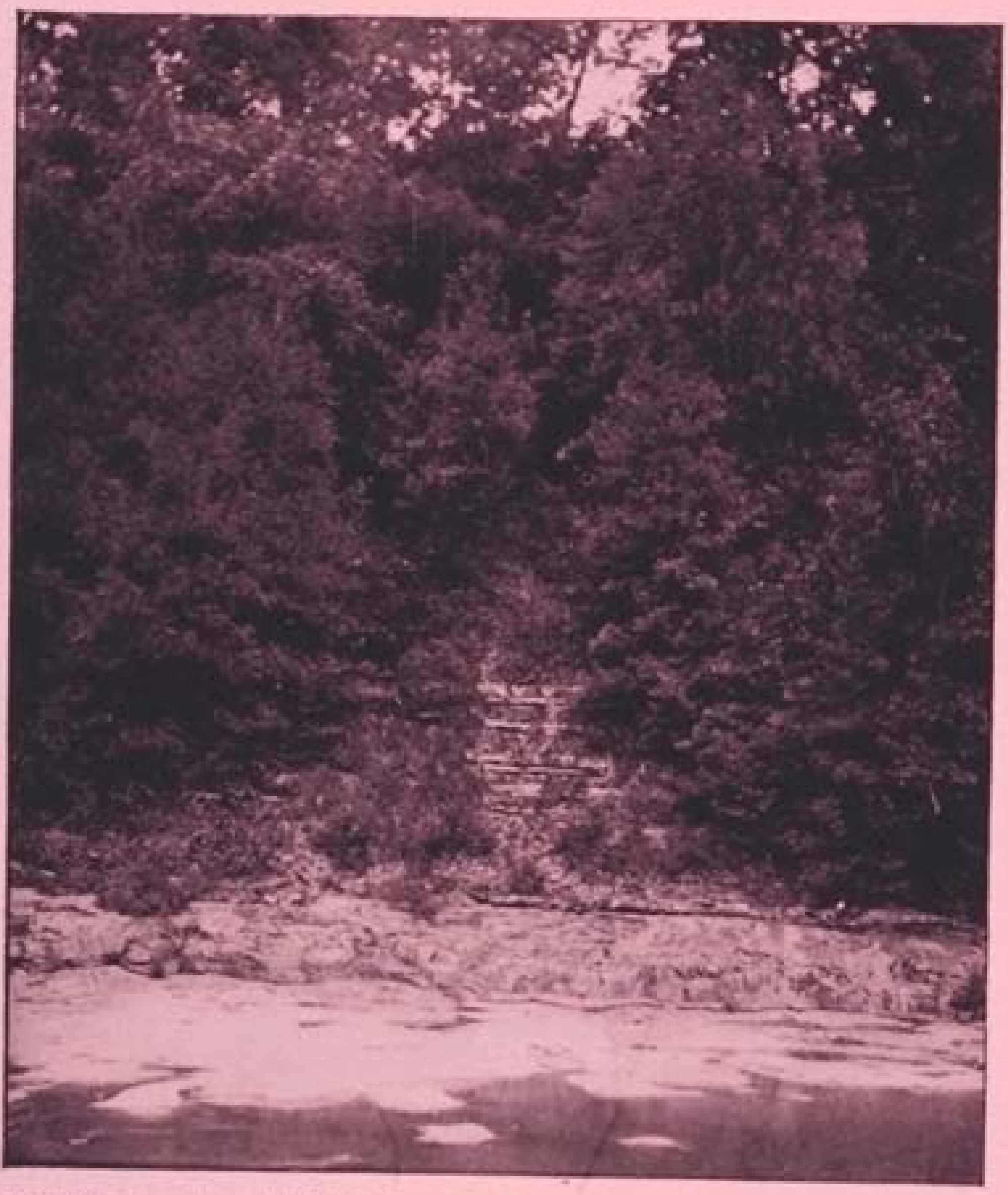
In the district about Little Falls the formation shows considerable variation in thickness, with rapid increase westward. On East Canada creek it is about 50 feet thick, with the Lowville always, and the Black River sometimes appearing beneath. Here it consists largely of gray, crystalline, fossiliferous layers, these being capped by thin bedded, blocky, black limestones, which become intercalated with shales and grade into the Utica above, the distinctive passage beds being of about the same thickness as the ordinary Trenton.

At Little Falls Prosser has assigned 104 feet to the formation, though but little of it is exposed in his section. The writer's measurements north of that point show an average of 80 feet of thickness, with again an equal amount of passage beds above.

Along West Canada creek, between Herkimer and Middleville, the Trenton ranges from 100 feet to 120 feet in thickness, the gray, crystalline, thin bedded type largely predominating in the lower half of the section and the dark colored type in the upper. Here also is an approximately equal thickness of passage beds, alternate shale and limestone layers, the limestone being identical in character with the dark colored Trenton type, and the shale being indistinguishable from the ordinary Utica.

Northward from Middleville there are many exposures of the Trenton, but most are of merely the lower portion, and there is

Plate 7



North bank of creek behind Canajoharie N. Y., exhibiting the relations of the Trenton limestone

no good continuous section. Northwestward also, about Newport and Poland, the sections stop in the lower Trenton, while away from the creek valley the drift cover is excessive. There is however a very good section in Rathbone brook, near Poland. White measured the section here and states its thickness to be 138 feet, with the Black River in place below.[1] He was unable to determine how great a thickness at the base should be regarded as being below anything shown at Trenton falls, where the base of the formation is not shown. The section also terminates in the Trenton and hence gives only a minimum value to the thickness. The incompleteness of the section hereabout is exceedingly unfortunate, since in the gorge of West Canada creek at Trenton falls, the type locality of the formation and distant only 14 miles from Middleville, the section shows a thickness of 275 feet (Prosser), or 284 feet (White), with neither base nor summit exposed.[2] Reference may be made to their papers for the details of the section, which consists mainly of thin bedded, dark blue limestones, with considerable admixture of the gray, crystalline beds, and with occasional massive layers; the whole capped by the 26 feet of massive, gray layers at Prospect [pl. 8 and 9]. Underneath this cap considerable shale is intercalated with the thin limestones through a thickness of 60 feet, giving a lithologic combination quite like that of the passage beds elsewhere. Nothing can be learned concerning these in the vicinity, unfortunately. According to White the lower portion of the Rathbone brook section underlies the base of the section at Trenton falls, but he does not hazard a suggestion as to the actual thickness involved. It seems however quite safe to say that the Trenton at Trenton falls is approximately 300 feet thick, more than double its thickness at Middleville, 14 miles away to the south of east. Only 27 miles farther to the southeast lies Canajoharie, with its 17 foot thickness for the limestone, the minimum for the State. Some of the latter diminution is due to overlapping unconformity, the base disappearing, but in either case it is obvious that the increase west from Middleville is more rapid than is the decrease eastward. Also that the increase in thickness is upward, implying that the

[1]N. Y. Acad. Sci. Trans. 15:84.

[2]15th An. Rep't State Geol. p.626 and footnote.

muds of the passage beds and Utica advanced on the region from the east, and Trenton conditions persisted longer westward. In other words, that, while the upper Trenton was accumulating in comparatively clear waters, in the Trenton falls region, incursions of mud were producing the lithologic combination of the passage beds about Middleville and eastward, while yet farther east shales were being laid down. This is by no means a new suggestion, though the stratigraphic evidence for it has not been so marshaled hitherto. Even if it be granted, it does not fully explain the sudden increase in thickness at Trenton falls, when compared with the much more trivial variations which characterize the whole length of the Mohawk valley below Canajoharie.

Concerning the formation along the west side of the Adirondacks, our knowledge is very fragmentary. As has been stated, the heavy drift cover on this side of the region is an effective bar to satisfactory areal work. Well to the north, about Watertown, conditions are much better, and the Trenton is magnificently shown. Emmons's descriptions show that it has the same lithologic characters here as at Trenton falls and elsewhere, consisting partly of dark, fine grained, and partly of gray, crystalline limestone, the former often interleaved with shales; also that often the summit is gray and massive, as at Trenton falls, which is not the case in the Mohawk and Champlain valleys. He states the thickness at Watertown to be about 300 feet, which, judging from his estimates of thickness of the rocks in other parts of the second district, is likely to be an underestimate.[1]

Quite fortunately the gas wells drilled within the past 20 years to the west and southwest of the region help to bridge the gap in the sections and furnish important data in regard to the thickness of the formation. The wells at Pulaski and Sandy Creek in Oswego county, which are 55 miles northwest of Trenton falls, and respectively 25 and 32 miles to the west of south of Watertown, have been described, and the sections interpreted by Professor Orton.[2] As is often the case, it is difficult to determine precise formation boundaries from the records, owing to a variety of causes. At Sandy Creek the thickness of the Trenton is uncertain but seems surely as much as 600 feet. At Pulaski the wells

[1] Geol. N. Y. 2d Dist. p.387–88.

[2] N. Y. State Mus. Bul. 30, p.434–48.

Trenton falls. View of the "Narrows" from lower end with Sherman fall in the distance

were drilled deeper, and from their records Orton constructed a generalized section for the vicinity, which allots a thickness of 600 feet to the formation (inclusive of the Black river and Lowville), and 200 feet to the Beekmantown beneath.[1] At Stillwater, 10 miles southeast of Pulaski, he indicates a thickness of 670 feet for the Trenton, and no allowance is made for the Beekmantown, which is surprising and suggests the query whether the Trenton has not been thickened at its expense. Here also the upper 300 feet are significantly referred to as "White Trenton" and the lower portion as "Dark Trenton," an arrangement of interest when compared with the type section.

A few wells are also reported on in Jefferson county, but the records given are very fragmentary.[2] In Adams township, next southeast of Watertown, three wells were drilled to the Precambric, which was reached at from 915 to 960 feet. Except for a few feet of drift the wells began in the Trenton and very near its summit. It seems incredible that the formation should be 900 feet thick here, but this includes the Black River and Lowville, and, in all probability, at least a small thickness of the Beekmantown, though it is not certain that that formation is here present. It is found however in outcrop not many miles away to the northeast, though it is not thick. However this may be, and making the most generous allowance possible, there yet remains a huge thickness which must be ascribed to the Trenton proper.

Notwithstanding their imperfections, these sections indicate with clearness that the thickness of the formation at Trenton falls is not a mere local matter, but that it is held, and much increased to the north, on the west side of the Adirondack region. As the same records show, the overlying Utica rapidly thins in the same direction.

In the Mohawk valley, west from Herkimer, the drill has also given corroborative evidence.[3] In the well at Ilion, only 3 miles west of Herkimer, the section shows 105 feet of Trenton, about what should be expected from its measured thickness along West Canada creek between Herkimer and Middleville. At Utica, 12 miles farther to the north of west, the Trenton is certainly 330

[1] *Op. cit.* p.442.

[2] *Op. cit.* p.456–59.

[3] Prosser, C. S. Am. Geol. 25:131–49; Geol. Soc. Am. Bul. 4:100.

feet thick, and perhaps more, the line between the Trenton and Beekmantown being difficult to draw with precision in that well. At Vernon, 17 miles west of Utica, 350 feet of the well section are assigned to the Trenton, and at Rome, 11 miles northwest of Utica, 375 feet. These thicknesses are not so great as those farther to the north, but the sudden increase in thickness between Ilion and Utica is quite analogous to that between Middleville and Trenton falls, along the more northerly line. At Chittenango, 35 miles west of Utica, the drill passed through 636 feet of apparent Trenton, and rested in that rock, a thickness directly comparable with that shown in Oswego and Jefferson counties.

Utica formation. This formation is, as a whole, surprisingly homogeneous all about the Adirondacks, consisting of fissile, black, somewhat calcareous, clay shales, which, like most carbonaceous shales, tend to split thinly and evenly and to have a somewhat slaty character. They become usually more fissile and less calcareous above, while below thin bands of shaly, black limestone commence to appear and increase in abundance, forming more or less of a transition to the Trenton beneath. Definite passage beds of the sort, of considerable thickness, are often found, but the evidence is not decisive as to whether they are, or are not, everywhere present in force. More likely they are not, and this seems specially probable on the west side of the region, and also in the lower Mohawk valley; whereas in the Champlain valley and the upper Mohawk region they have much importance. These beds are also a mixture faunally, the rather restricted fauna which characterizes the pure Utica occurring with a considerable number of Trenton forms, so that the line of demarcation between the two formations will vary greatly, according as it is drawn at the first appearance of the Utica fauna, on the one hand, or at the final disappearance of the Trenton fauna on the other. The case is one where it seems certain that the two contrasted faunas were living in the same basin at the same time, each in situations where the conditions were favorable, and each under different sorts of conditions; and that the one set of conditions increased in area occupied, and its fauna spread, at the expense of the other.

In the Champlain valley it is difficult to arrive at any precise notion regarding the thickness of the formation. It is the

great, and also that it diminishes somewhat westwardly, so that it has but little over half the thickness about Utica that it has in eastern Montgomery county.

North and west from Little Falls, it will be remembered that the Trenton thickens, rapidly and suddenly, and it is of interest to note the coincident thinning of the Utica. Commencing at the north, Walcott's measured section along Sandy creek, in Jefferson county, shows the Utica to be 180 feet thick, with an additional 100 feet of passage beds to the Lorraine shales above.[1] In Oswego county Orton reports, at Central Square 729 feet of shales (Pulaski and Utica) between the Oswego sandstone and the Trenton, of which 150 feet are ascribed to the Utica; at Oswego 597 feet of shales in the same interval; at Stillwater 643 feet, of which 113 are thought to belong to the Utica; about Pulaski 300 feet to 500 feet of shales, of which 100 feet to 250 feet represent the Utica thickness; and at Sandy Creek (Oswego, not Jefferson county), 250 feet to 300 feet of Utica.[2] These are vastly thinner than the Mohawk sections and overlie in general from 450 feet to 650 feet of Trenton, usually in a definite inverse ratio, a strong indication of the contemporaneity of the upper Trenton and lower Utica in the contrasted districts. Moreover, Prosser shows 1020 feet of shales in the Vernon well, of which 300 feet are Utica, overlying 350 feet of Trenton; 873 feet in the Chittenango well, of which 233 feet are Utica, overlying 60 feet of passage beds and some 600 feet of Trenton; 505 feet at Baldwinsville, north of Syracuse, the amount to be attributed to the Utica not being stated; and at Auburn 557 feet of shales, the drill resting in the Trenton 240 feet below its summit.[3] These show definite Trenton thickening, and Utica thinning westward, though the change is more gradual than it is to the north.

Lorraine formation. While no paleozoic rocks younger than the Utica shale are found in sufficient proximity to the Adirondack region to justify any detailed discussion of them in a consideration of Adirondack rocks, yet some of them are sufficiently involved with its past history, as will appear beyond, to deserve some notice.

[1] *Op. cit.* p.348.
[2] N. Y. State Mus. Bul. 30, p.456, 449, 442, 437.
[3] Am. Geol. 25:152, 161.

Plate 9

Trenton falls. Sherman fall from above the "Narrows"

On the south and west sides of the region, the Utica shales are overlain conformably by a group of shales and sandstones, often with passage beds between; and the group has usually a large thickness, as the section and well records just quoted demonstrate. There is no direct evidence that equivalent rocks were ever deposited in the Chazy basin of the Champlain valley, but neither is there any weighty evidence that they were not. South of the Mohawk, however, and all along the west side of the region, they appear in force. The above quoted records show that the formation thins westward through the Mohawk valley, is thinnest at Utica, where only its base is present, and thence thickens rapidly to the north and west. Walcott has given a thorough discussion of the evidence, showing that it argues for a shallowing of the sea along the Utica meridian early in Lorraine times, thinning the section there, and preventing thereafter a commingling of the western (Lorraine) fauna, with the forms to the eastward of the barrier, which hence separated the eastern Mohawk basin from that of the interior.[1] It is by no means improbable that this uplift at Utica is but part of a greater movement, which extended thence to the northeast, bringing much, if not most of the Adirondack region above sea level and causing also cessation of deposition in the Chazy basin.

The great thickness of the Lorraine rocks, both in the eastern Mohawk region and in Jefferson and Oswego counties, together with the fact that their present line of outcrop is owing to long continued, surface erosion, and that the effect of this erosion is to cause the line of outcrop continually to recede from the Adirondacks, sufficiently indicates that in the past they must have extended in over them, likely for several miles, and that in some considerable thickness; and that during Lorraine times a considerable area, specially on the northwest and the southeast, remained yet submerged, in spite of the uplift described above. In addition, it is by no means impossible that some of the later Siluric rocks may have overlapped on the southern and western margins of the region, though this is much more open to question than is such a former extension of the Lorraine rocks. Certainly, the general tendency to subsidence over the district, initiated in

[1] Geol. Soc. Am. Bul. 1:344–50.

Plate 10

Falls over Utica slate in the ravine behind Canajoharie N. Y.

Cambric times, was checked and replaced by the contrary tendency during Lorraine times, a tendency which has, in the main, persisted to the present.

Helderberg submergence. On the south and west of the Adirondack region the Lorraine rocks are successively overlain by the Medina, Clinton, Niagara, Salina and Waterlime deposits. These are more likely to have overlapped on the west side of the region than elsewhere. On the south they thin and disappear in going eastward, showing that they are approaching a shore line in that direction, and that the lower Mohawk region was not receiving deposit during most of the interval. Then ensued a change at the extreme east, a considerable depression being formed there, in which marine limestones accumulated, whose fauna entered the basin through some connecting channel with the eastern sea. These rocks do not extend westward as far as the upper Mohawk region, showing that that district did not participate in the depression, or else that a barrier was formed there, separating the eastern basin from that to the west, waterlime conditions persisting in the latter after they had been brought to an end in the former. From Albany these rocks extend far south into the Appalachian region, as deposits in a long, trough-shaped basin. As to the northern limits of that basin, we are in ignorance, the deposits having been swept away by erosion; but, since it is known that the present line of the St Lawrence was also depressed during that time, deposits of that age occurring on St Helen's island, near Montreal, it is rendered quite likely that the Champlain and upper Hudson valleys were also involved, forming a channel which furnished a connection with the outer sea by way of Montreal. If such were the case, the subsequent removal of the deposits has obliterated all the evidence on which a demonstration might be based. There was some connecting channel with the outer sea; there may have been more than one; the line suggested would furnish a natural route.

Summary of early Paleozoic oscillations of level. The evidence which is given by the distribution, character and thickness of the several Paleozoic formations which were deposited on, and around, the Adirondack region, as to the oscillations of the land surface,

has been treated in some detail in the foregoing pages, but a concise summary of it may well find a place here.

The Potsdam is confined mainly to the north and east sides of the region. It comes around into the Mohawk region, but is thin there and fades out to a vanishing point about midway of the valley. It does not appear at all on the west side of the territory. It is thickest on the northeast, in Clinton county, and there alone is any great thickness of its peculiar, basal portion to be found. To the south and west the formation thins by disappearance of this base, and it would seem therefore that deposition must have commenced on the northeast and advanced progressively westward and southward, so that by the close of the Potsdam the northeastern district had undergone large submergence, whereas on the southwest the shore line was yet outside of the present Precambric margin, and the amount of subsidence had been trifling; that is, that there existed a large, unsubmerged area on the south and west at the close of Potsdam time.

The formation was laid down on a comparatively even floor of older rocks, whose evenness was mainly due to previous protracted wear on it while a land surface; but, in spite of the *comparative* evenness, the floor shows much minor irregularity, whose amount seems to increase with increasing thickness of the overlying Potsdam. All the workers on the north and east sides of the region have observed and commented on the irregularity of the floor, which sometimes amounts to some hundreds of feet. In the Mohawk valley region the floor seems to have been exceedingly even and flat, much more so than on the north. Since the former was barely, or not at all submerged by the Potsdam sea, while the latter was early invaded by it, the one did and the other did not experience subaerial erosion during Potsdam time, this furnishing an obvious reason for greater smoothness in the former, though it may not be the whole reason.

The upper division of the Potsdam would seem plainly to be a marine sand deposit. Quite likely this is true of the middle division also, though it is not so certain because of lack of fossils. It seems possible that the basal portion, which is developed only on the northeast, may represent a flood plain deposit under conditions of climatic aridity. The red color and the undecayed char-

acter of the feldspar grains in this portion may perhaps be thus explained.[1]

Above the basal division the rock becomes a purely quartzose one, and the red color disappears. This middle portion of the formation, as shown in Clinton county, becomes however its base to the west and south, because of the gradual encroachment of the subsidence in those directions, explaining the lack of arkose in St Lawrence county and in the Mohawk valley. Because of the occurrence, in St Lawrence county, of a quite pure, quartz sandstone resting on an uneven surface of crystalline rocks, Smyth has argued for a humid climate with rapid weathering at the time; and that, owing to the resistant character of the underlying rocks, the waves did not act for a sufficiently long time at a given level to plane away the rock floor to an even surface, though the time was sufficiently long to weather and triturate all minerals save the extra resistants quartz.[2] The writer quite agrees that a change in climate is probably indicated by the change in the rock character.

The offshore mud deposits of Potsdam time are nowhere exposed to view about the region. Some slight deposit of limestone took place, as shown by Walcott for the district about Saratoga, and by the well records published by Orton for the Oswego county region. The formation tends often to become somewhat calcareous or rather dolomitic, above, and everywhere grades into the overlying Beekmantown through a series of passage beds, which show rapid alternations of the two sets of contrasting conditions, the one gradually overcoming the other, so that subsidence must have been progressive, and no great time interval could have elapsed between the two deposits.

The bulk of the Beekmantown formation is composed of sandy dolomites, all very barren of fossils. They seem to the writer to indicate shore conditions and to a considerable extent "salt pan" conditions.[3] With the oncoming of Beekmantown time subsidence

[1]The writer has long been of the opinion that the early Potsdam climate was an arid one; and recent correspondence with Mr van Ingen has disclosed that he is also disposed to hold a similar view and is investigating the matter with the development of new and interesting evidence.

[2]N. Y. State Geol. 19th Rep't 1899, p.r100–2.

[3]Dana, J. D. Man. of Geol. ed. 4, p.133.

commenced on all sides of the Adirondack region; but, as was the case also in the Potsdam, it was most pronounced on the northeast and diminished in amount toward the west and south. The formation must have encroached on the Adirondack island on all sides, greatly diminishing its previous area. On the south side specially a large transgression of the sea on the former land took place, since the Potsdam shore line had been an unknown distance to the south of the present line of the Mohawk valley, while the Beekmantown has a thickness of from 300 feet to 500 feet there, and its shore must have lain several miles to the northward. On the west side of the region but little subsidence took place, and the Beekmantown shore line lay to the west of the present Precambric border there. In the Champlain region the formation has treble the thickness that it has along the Mohawk, and the transgression of the sea on the northeastern portion of the region must have been of vast extent. The Adirondack land mass must certainly have been an island during the Beekmantown, whose area was small compared with the present size of the region, and which lay mainly in its western portion, extending eastward for an unknown distance, greatest on the south side.

Then conditions changed, and the downward movement was replaced by an upward one, which caused cessation of deposition on the south and west sides of the area, brought a large but unknown amount of the previously submerged tract above sea level, so that the Beekmantown island was greatly extended in those directions, and shut off communication between the basin on the southwest and that on the northeast. The latter district did not feel the upward influence, but continued to subside, and the limestones and dolomites of the Cassin formation were deposited on the normal Beekmantown. The abundant fauna found fossil in these beds and absent from the Beekmantown beneath, must have entered the basin from the east or north, arguing for extended depression and open sea connection in one or the other, or both, directions.

The depression on the northeast persisted throughout Chazy time, though likely with interruptions, of which the most important is indicated by the basal sandstone of the Chazy. Like the preceding Cassin subsidence, this diminished rapidly in amount

southward, so that the rocks disappear through thinning at the upper end of the Champlain valley, the middle division of the formation being the last to vanish. Following the deposit of the upper beds, uplift ensued, or at least a cessation of subsidence and of deposit; there is little or no indication of wear at the Chazy summit, so that the surface could not have been raised much, if any, above sea level.

The large amount of subsidence on the northeast during Potsdam, Beekmantown and Chazy times must have involved that entire section of the present Adirondack region, since the Precambric floor of the district was not vastly irregular, nor could its seaward inclination have been great. The amount of rock thickness of these three formations which was deposited in the lower Champlain valley was from 3500 feet to 4500 feet, so that the upper Chazy deposits must have been carried far into the present heart of the Adirondacks by their overlap on the old land slope.

During Chazy times the Cassin elevation on the south and west sides of the region persisted, and no deposits of Chazy age were formed. The land was in fact sufficiently elevated to permit a certain amount of erosion of the Beekmantown deposits which formed its surface. The uplift was accomplished without tilting or folding of the rocks, except in a very minor degree, and in general the Lowville rocks appear to overlie the Beekmantown conformably. In some sections, as at Canajoharie, there is a plain discordance in dip between the two formations, owing to a very slight folding of the Beekmantown [pl.7]; but in most places nothing of the sort can be made out, though a comparison of several sections usually suffices to show that the Lowville does not always rest on the same bed of the Beekmantown. The surface was planed down to great evenness, arguing for either a long continued period of wear or else for a very low altitude and gentle surface slope.

The uplift of the northeastern region at the close of the Chazy was coincident with, or somewhat closely followed by, a movement of downward character on the south and west, which much diminished the land area there, bringing the shore line in close to the present Precambric margin of the region. The

Lowville limestone was deposited in these waters. The movement of the region was apparently pivotal, along a northwest and southeast axis which crossed at the upper end of the Champlain valley, sinking on the one side being accompanied by rise on the other. In that district this line formed the southern shore line of the Chazy sea and also the northern shore line of the Lowville sea. The thinness and the intermittent character of the Lowville formation, along the present line of the Mohawk valley, would indicate either that the Lowville shore line was not far away to the north, and that the subsidence was only trifling, or else that, after the deposition of the material, an uplift occurred and considerable wear took place. So far as the slender evidence goes, the former would seem to have been the case, since the unconformity at the base of the Lowville is much more pronounced than that at its summit, in fact there is little sign of wear at the latter horizon; while the not infrequent occurrence of alternating Lowville and Black River conditions would seem to bind the two formations rather closely together. It is therefore thought probable that the Lowville sea extended but little north of the Mohawk line and hence encroached little or not at all on the Adirondack region from the south.

On the west side of the region the formation has much increased thickness and apparently for many miles rests directly on the old, Precambric floor. Its thickness would argue that it must formerly have extended in several miles over the western Adirondack border, and farther than any of the preceding seas had done.

During Lowville time therefore the bulk of the Adirondack region was a land area, with wide extent to the north and east beyond the present boundaries of the district, with its southern shore line rudely corresponding to the present Precambric border on that side, and its western edge alone somewhat submerged.

The Black River limestone follows the Lowville on the south and west, with no sign of a structural break between the two. In the Mohawk valley the formation is thin and sometimes absent. In some cases its nonappearance is definitely due to the fact that the Lowville deposits had not completely filled the slight depressions in the Beekmantown floor on which they were laid down,

and the added thickness of the Black River was also insufficient completely to fill them. In these instances it seems clear that the slight elevations on which no deposit took place must have existed as shoals, and that hence the water was very shallow, and the shore line close at hand, as seems to have also been the case during the Lowville. There are sections, as in the Moore quarry at Pattersonville, measured by Prosser, in which the Black River rests directly on the Beekmantown, though the Lowville occurs thinly at its proper horizon, no great distance away, and such a section is demonstrative of uneven surface. On the other hand, the writer's work in the Little Falls region has shown that the Black River there has a very patchy distribution, and that about Middleville it is definitely absent, though the Lowville occurs there in considerable strength, and this is thought to point to an unconformity between the Black River and Trenton, the Black River being absent because of uplift and wear, after its deposition and before the beginning of the Trenton. Not unlikely the strong unconformity at Canajoharie is in part due to wear of this date, and not all to be ascribed to the period of Postbeekmantown erosion. This uplift seems to have been localized here at the southeast, since only there is the Black River found to be lacking. In the Mohawk region then, the shore line was close at hand and was irregular, though not so much so as at the commencement of the Lowville, and the one formation followed the other with no sign of a break, the two deposits combined nearly, but not quite, filling up the depressions; thence ensued an uplift about Little Falls, which brought about removal of the Black River through wear and caused the Trenton there to rest on the Lowville.

With the oncoming of Black River time, rapid subsidence seems to have been initiated on the east side of the region, the Chazy basin becoming again submerged; and the deposits thus laid down must have encroached as widely into the heart of the Adirondacks as the previous Chazy deposits had done. On the west side of the region also the formation is everywhere present, and thicker than on the south, so that the Black River sea was continuous around the region, and must have widely submerged it. There must have remained unsubmerged, however, an island of con-

siderable size, occupying approximately the same position as the previous Beekmantown island, but with considerably diminished area, specially on the western side. As in that case, this land was massed on the south and west.

The only stratigraphic evidence of a break between the Black River and Trenton, seems to be in the upper Mohawk region, where there is certainly a slight unconformity, with locally entire removal of the Black River. In Trenton times also the Mohawk region was but slightly submerged, and the formation is but thinly developed. This would argue some shore line near at hand, and Kemp's study of the Paleozoic outlier at Hope demonstrates the presence of land near the southern Adirondack margin, during at least the early Trenton.[1] In addition, it seems to the writer that this outlier presents suggestive evidence of the truth of the arguments advanced in the preceding pages, regarding the small extent of the invasion of the southern Adirondacks by the successive seas. In this outlier Potsdam, Beekmantown, Trenton and Utica strata are all present, and, with the possible exception of the last, none of them seem to have been deposited in great thickness, though during intervening periods of wear some thickness of each may well have been removed. Apparently the deposits indicate the near vicinity of a shore line to the north in Potsdam, Beekmantown and early Trenton times, and their thinness and character are due to such proximity.

Throughout most of the Mohawk valley region the Trenton has no great thickness, indicating but slight subsidence during its deposition. On the east and west sides of the region, however, it attains large thickness, hence subsidence was in progress on all sides of the district, and the encroachment of the sea over it must have considerably exceeded in extent even that of the previous Black River sea. The Black River island must have been nearly, if not utterly, wiped out by the close of the Trenton.

Then came in the muds of the Utica, appearing first on the east side of the region and gradually encroaching westward. Ruedemann's argument for the extension of the Utica over the entire Adirondack region, based on the parallel alinement of the graptolite fronds found fossil in the shales, as indicative of a uniform,

[1] 18th An. Rep't State Geol. 1898. p.145-52.

unopposed current, seems to the writer to be conclusive.[1] The argument based on the thickness of sediments about the Adirondacks, and their necessary wide overlapping on the gentle slopes of the Precambric old land, also seems conclusive as to complete submergence during the Utica, the thickness and the evidence of gentle land slope being ample to warrant the conclusion. If any land remained during the Utica, it could have consisted of nothing more than a few, low, insignificant islands, and such must have been along the southern margin of the region. The slight amount of Trenton submergence in the lower Mohawk region may well indicate that, during a portion of Trenton time, there existed here a shoal barrier between the eastern and western basins.

The Utica was brought to a close by the shallowing of the waters, which may well have brought a considerable part of the Adirondacks, specially on the north, above sea level, though this is mainly conjectural. During Lorraine time, which followed, a shoal was developed in the region about Utica, probably extending thence northeastward, which separated the eastern and western waters. This would seem definitely to imply the emergence of land to the northward, and likely by the close of the Lorraine a large part, if not the whole of the Adirondacks, was elevated above sea level. The following Medina, Clinton and Salina waters washed the western and southwestern sides of the region only and may well have somewhat encroached on its margins. Then came elevation on the west, and the Helderberg depression on the east, the latter probably involving the eastern border of the district. The succeeding Devonic deposits may have reached the southern rim of the area, but could hardly have invaded it to any considerable extent.

Paleozoic igneous rocks. On both the eastern and southern margins of the Adirondack region, the Paleozoic rocks which fringe it are found to be cut by igneous rocks, mainly in the dike form. In the Champlain region these rocks cut, and are therefore younger than, the Utica shale, the youngest of the Paleozoic rocks to be found in the district. In the upper Mohawk district the dikes also cut the Utica shale.

[1] Am. Geol., June 1897 and February 1898, p.75.

The Champlain eruptives of this period have received detailed description from Kemp.[1] They are more abundant in Vermont than on the New York side of the lake, and on that side seem mostly confined to Essex county, and to the near vicinity of the lake shore. They extend into Clinton county however, in which six small dikes belonging to this group have been found, are still more abundant in northern Vermont and extend thence northward into Canada. The Adirondack region seems to have been on the outer border of the region affected by the igneous activity.

Two contrasted groups of rock are present, the one light colored and acid, the other black and basic. The former are classed as bostonites by Kemp, the latter as camptonites, monchiquites or fourchites, according to their mineralogic character. As in the case of the older, Precambric dikes, the acid rocks seem less numerous than the basic and with a more restricted distribution, though these differences are in much less noticeable degree than in the earlier case.

Trachytes (*bostonites*). In New York State rocks of this group seem confined to Essex county, at least none have been discovered elsewhere. Kemp describes them as of prevailing light color, creamy or brownish white usually, but sometimes a light chocolate; of rough and granular feel and a fracture like that of trachyte. Phenocrysts are not numerous in general and are nearly always of feldspar, quartz having been noted but rarely. The ground-mass is constituted of minute feldspar laths with usually well marked flow structure. Between the laths small particles of interstitial quartz are sometimes to be detected. The feldspar is both orthoclase and anorthoclase, little or no plagioclase being present. A considerable amount of hematite is present in minute, disseminated scales, but aside from the above no certain primary minerals can be made out. Calcite, quartz, kaolin and limonite are the principal materials resulting from alteration, and in general the rocks seem hardly as fresh as the older syenite porphyries of Clinton county, which they much resemble.

At Cannons point, just north of Split rock, Kemp has described a large mass of this rock as a sheet, or laccolite, the exposures

[1] U. S. Geol. Sur. Bul. 107.

apparently not being sufficiently extensive to permit of certainty in the matter. This is the only known instance in New York where any of these rocks occur in other than the dike form.

Basic dikes (*camptonites, monchiquites and fourchites*). Of these basaltic rocks the main mineralogic constituents are a basic feldspar, usually andesin or labradorite, augite, brown hornblende, olivin and biotite. The camptonites are feldspar augite, or feldspar hornblende rocks; in the monchiquites and fourchites the feldspar retreats or disappears, thus separating them from the camptonites, and they are distinguished from each other by the presence in the former rock, or the absence in the latter, of olivin. Some glassy base is usually present, specially in the latter two rocks, and they not infrequently contain analcite.

Camptonites are mostly characterized by the presence of brown, basaltic hornblende in sharply bounded crystals. It is often more or less replaced by augite, up to complete disappearance of the hornblende. Such rocks differ but little from diabases, the difference being a minor, structural one; in the diabases the augite formed somewhat later than the feldspar and accommodated itself to the feldspar outlines, instead of presenting its own outlines; in the camptonites it formed earlier and is more apt to have its normal outlines. In most cases at least some brown hornblende is present, and serves to distinguish the two rocks. In many of the dikes there is no augite whatever. Magnetite is the only other mineral uniformly present. Some little glassy base is apt to be at hand also.

The monchiquites consist of olivin, augite, hornblende, biotite (one or all three of the last named), and a glassy base. Like the camptonites these are apt to be porphyritic. Analcite is not infrequently present. The fourchites are similar except for the lack of olivin, and consist principally of augite, though with some hornblende or biotite. They are much rarer than the monchiquites in the Champlain district. A related rock, ouachitite, in which the biotite predominates and augite retreats, has not been so far noted in the district, though biotite is abundant in several of the dikes.

Age of the Champlain dikes. Kemp was the first to note that these acid and basic dikes of the Champlain region are of the

sort which usually accompany nephelin syenite igneous bodies, but that such are absent in the immediate region, though occurring in Canada to the northward, and to the eastward in New England. It is of course possible that masses of the sort are present in the Champlain region but are as yet uncovered by erosion. It would seem however that these Champlain dikes are on the southeast margin of a considerable region which was affected by the igneous action, and that evidence regarding their age may be sought in the entire affected area. In the immediate Champlain region no closer determination of their age can be made than that they are younger than the Utica shale, which some of them cut. There would seem to be no question that they are older than the Trias, or are of Paleozoic age, since the igneous rocks of the Trias are of quite different sort, and rocks like these are nowhere found associated with them. The evidence given by the exposures on St Helen's island, near Montreal would indicate that these rocks are at least as young as the early Devonic; and the writer has recently come to the belief that a Carboniferous age must be assigned to them, though this is not possible of demonstration at the present time.

Chemical analyses. No very good and complete analyses of these Champlain eruptives have yet been made, though they closely conform to similar rocks elsewhere. Such as are available are given by Kemp in United States Geological Survey, bul. 107. It is however of interest to note their quite striking similarity in composition to the earlier dikes, which preceded them in late Precambric time. The camptonites and monchiquites are chemically very close to the earlier diabases, and an equally strong resemblance obtains between the bostonites and the syenite porphyries.

Igneous rocks of the upper Mohawk region. Smyth, G. H. Williams, Darton and Kemp have described very basic rocks, of the peridotite class, about Manheim, Syracuse and Ithaca.[1] These rocks are only remotely connected with the Adirondack region, but completeness would seem to make desirable some considera-

[1]Darton & Kemp, Am. Jour. Sci. June 1895, p.456-62; Kemp, J. F. Am. Jour. Sci. Nov. 1891, p.410-12; Smyth, C. H. Am. Jour. Sci. Ap. 1892, p.322-27: ——Am. Jour. Sci. Aug. 1893, p.104-7; Geol. Soc. Am. Bul. 9: 257-68; Williams, G. H. Am. Jour. Sci. Aug. 1887, p.137-45.

tion of them. They occur for the most part in very irregular dikes, often of very small width. They belong to the peridotite class of igneous rocks, the most basic of any. Such rocks are prone to rapid decay, and these are no exception, all of the known exposures being considerably, and many of them highly altered and rotted.

In general their mineralogic make-up is of biotite, olivin, pyroxene and melilite, with accessory magnetite, perovskite and apatite. Wherever sufficiently fresh material has been forthcoming, the presence of melilite has been noted, Smyth having early shown its presence in the Manheim rock and having recently detected it in some new material from the Syracuse vicinity. Alnoite is the name applied to a melilite holding peridotite. All the rock contains biotite and olivin in quantity, but the pyroxene is much more irregular in its occurrence. It is rare or else absent in the Manheim rock; while Kemp has shown that it is the main mineral of the ground-mass in the Dewitt dike near Syracuse. Likely some glassy base was present in nearly all occurrences. In all except the freshest rocks the olivin has gone to serpentine, and Smyth has described in detail the processes of alteration and decay.

Chemical analyses. Since these rocks are all considerably altered, analyses of them are not trustworthy if what is sought is the actual composition of the fresh rock. Yet, if the analyses are made from the freshest possible material they will give good evidence of the general character of the igneous magma, and of the closeness of correspondence of the rocks from the separate occurrences.

	1	2	3	4
SiO_2	36.8	33.8	35.25	37.44
Al_2O_3	4.16	6.84	6.1	28.6
Fe_2O_3	n. d.	12.26	8.53	11.92
FeO	8.33	n. d.	5.6	n. d.
MgO	25.98	21.38	20.4	1.97
CaO	8.63	9.5	7.4	5.45
Na_2O	.17	n. d.	.7	.97
K_2O	2.48	n. d.	2.88	1.02
Loss[1]	12.25	15.2	12.4	12.67
Sum	100.27	98.98	99.26	100.04

[1] In no. 1 includes $H_2O+6.93$, $H_2O-.51$, CO_2 2.95, TiO_2 1.26, P_2O_5 .47, MnO .13; in no. 3 includes TiO_2 2.25.

1 Dewitt dike near Syracuse. Darton & Kemp, *op. cit.* p.461, analyst, H. N. Stokes.

2 Manheim, Herkimer co., C. H. Smyth, *op. cit.* p.325, analyst Smyth.

3 Manheim, Herkimer co., C. H. Smyth, *op. cit.* p.262, analyst Smyth.

4 Ithaca, J. F. Kemp, *op. cit.* p.412, analyst W. H. Morrison; analysis incomplete, and the alumina and magnesia determinations obviously incorrect.

The first three of these analyses are of *fairly* fresh material, when the character of the rock is taken into consideration. They suffice to bring out clearly the close relationships of the rocks from the different localities, as evinced by the low silica and alumina and the very high magnesia. While these characters belong to the general rock group to which these rocks pertain, they are the only igneous rocks of the group known in the State, and therefore clearly represent outflows from the same subterranean source. So far as known, they are confined to the central part of the State, but the three localities are so widely separated that unquestionably others will be forthcoming.

ROCK STRUCTURES

The rocks of the Adirondack region may be separated into three main groups of widely separated age, owing to the fact that there have been three main periods of rock formation in the region, separated by protracted intervals of wear. The Precambric rocks constitute the first group, the early paleozoics the second, and the pleistocene deposits the third. The last are so recent as to be in substantially the condition in which they were deposited, unconsolidated masses of glacial deposits and of marine and fresh-water sands and clays. A vast time interval separates them from the paleozoics, which are all thoroughly indurated rocks, but which are otherwise not greatly altered from their original condition, though they have suffered somewhat from earth stresses and movements. Another vast time interval separates these from the Precambric rocks, and the latter underwent profound changes in character during this interval. They therefore present structural features which are confined to them, as well as others which they share with the Paleozoic rocks.

Foliation

In the Adirondack region the Precambric rocks alone have suffered metamorphism, but they are so profoundly metamorphosed, the late dikes always excepted, as to have been vastly

altered in character. The change consists, for the most part, in a recrystallization of their constituent particles, destroying their original textures and structures and developing new ones. The Grenville and Saranac rocks are the ones most affected and in large part have their original characters utterly destroyed. In the great igneous masses the changes are not so widespread and profound, so that often there is at least a partial preservation of their original characteristics.

The old sedimentary rocks have lost all traces of lamination and nearly all signs of original bedding; they have undergone complete recrystallization, entirely obliterating their old textures, and, as a result of severe compression, have had a development of cleavable minerals along certain parallel planes, the mineral particles having a common orientation. This gives rise, on the part of the rock, to a capacity to split along such planes, and the structure is a variety of cleavage, and is known as foliation. Sometimes this new structure is parallel to the old bedding planes and sometimes it is not; often the latter can not be made out at all. In general the old limestones, now converted into coarse marbles, are the only sedimentary rocks which are not now foliated. This is because of the facility with which such rocks become crystalline, their rather uniform composition, such that they consist mainly of one mineral, and their comparatively great plasticity under pressure.

The great igneous masses are, in general, much less foliated, though this is not true of many of the smaller ones, and specially not of the older ones, those that seem to be of Grenville age. In considerable part the absence of foliation in much of the igneous rock is thought to be due, as in the limestones, to the fact that the rock is largely constituted of a single mineral. Much of the anorthosite, and to a lesser degree of the syenite also, is quite purely feldspathic, the minerals which are most effective in producing foliation being present in but slight quantity, or not at all. Such rocks are often badly mashed and granulated, indicative of the great pressures which they have experienced, but with no production of foliation. But, with change in the rock composition, with the formation in quantity of biotite, amphibole or pyroxene, more or less foliation is pretty sure to be induced in

the rock. In all the large igneous masses, the general more basic character of their peripheral portions has resulted in the formation of such minerals there, hence their tendency to pass over into gneisses at their borders, a tendency so widespread as to be practically universal. The gabbros of the region possess throughout a large proportion of such minerals, and in the writer's experience they, though the youngest of the igneous rocks of the group, are much more uniformly gneissoid than are any of the others. True, comparatively unchanged cores remain in nearly every case, so that the original character of the rock may be demonstrated, but this is usually of small bulk in comparison with the hornblende gneiss, produced from it by metamorphism.

In many of the granites also there is a great scarcity of the foliation-producing minerals, the rock being mainly, or wholly, constituted of quartz and alkali feldspars. These rocks are apt to lack foliation, and then not infrequently have a somewhat similar linear structure, the quartzes being drawn out into spindles and pencils, with a direction corresponding to the foliation direction of the inclosing rocks. A similar tendency may often be noted in the more quartzose syenites. This structure has only been noted in these quartzose rocks, hence a natural tendency to attribute it to the mineral composition. But coupled with that may well have been such slight differences in the mean and maximum pressures in the rock that it suffered nearly equal shortening in two directions at right angles, and elongation merely in the third.[1]

The foliation in the Precambric sediments seems, in general, to be parallel to the bedding, so far as the latter may be made out. Over the greater part of the district the dips are comparatively steep, ranging in general from 20° upward. Judging from the writer's own experience, and from the published data of other observers, the strike is seldom uniform over any considerable area, but is now to the northeast, now to the northwest. North and south, or east and west directions are much more infrequent. The shifting of the strike direction indicates that we are dealing with folded rocks, and that this is actually the case is readily demonstrated in the Grenville sediments, but with difficulty elsewhere. It is also evident that the folds

[1]Hoskins, L. M. U. S. Geol. Sur. 16th An. Rep't, p.870.

have a considerable pitch, and the writer's impression is that in the northern part of the region at least, the pitch is to the north. The major folds would seem to be broad and not excessively steep, but their limbs are corrugated by minor folds also, and it is in these that the steepest dips are obtained.

The great igneous batholites of the Adirondacks are massed in the east center of the region. Going west and south, a zone is passed through marked by increase in Grenville sediments and diminution of igneous rocks. On the west and south the sediments largely predominate. It is in these areas that the folds must be worked out, provided they can be worked out at all. If so, the knowledge thus obtained may be, perhaps, successfully applied to the elucidation of the structure of the more difficult interior area, more difficult because of the much larger content of poorly foliated igneous rocks. The writer's work has been mainly in the latter district. It ought to be possible with good maps and careful areal work, to make out the axes of at least the larger folds. The folding was certainly done in Precambric times and while the rocks were buried at some considerable depth; hence it long preceded the period of diabase eruption, and these dikes are wholly unaffected by it.

Folds

Aside from the folding of the Precambric rocks, just noted, which was produced in Precambric times, the rocks of the region are but slightly folded. Along Lake Champlain the Paleozoic rocks are thrown into a series of very gentle folds, which have subsequently been so much faulted that the folding is not always apparent. Across the lake in Vermont the folds become rapidly more pronounced, but on the New York side only a trifling amount of folding has taken place. The dips are in general very low, and in many cases so flat that they are made out only with great difficulty. They are almost always below 10° and usually below 5°. In the few instances where they are steeper, the cause is usually found to be the tilting of a small fault block, or drag in the vicinity of a fault. A steep dip may usually be taken as an indication of proximity to a fault. However, the rocks are unquestionably slightly folded, marking in all probability merely the waning effects of the force

which produced the greater folds to the eastward. So far as observed, the folds trend nearly north and south. Minor folding, of sometimes considerable amount, is often observed in the near vicinity of faults, and in many cases at least is a result of the faulting, being apparently due to differential movement along the fault plane.[1] Such folds are small and rapidly die out with recession from the fault plane.

Westward, along both the north and the south sides of the region, evidence of folding is progressively less evident. That there are low undulations of the strata can not be doubted, but such are found in nearly all districts, of even the least disturbed rocks, and can be located only with the most painstaking care, if at all. Slight local folds, sags is a better term, are not uncommon in the limestones of the Mohawk valley, but seem to be local and not regional structures.

Faults

Precambric faulting. The location and tracing out of faults in the Adirondack Precambric is an exceedingly difficult task, and, in so far as they have been located, their recognition has depended more on topographic than on structural evidence. The discrimination between Precambric and later faulting is trebly difficult, and for the most part has not been attempted. Practically all topographic indications of Precambric faults must have been obliterated during the protracted period of Prepotsdam wear on the then land surface of the region. At the present day large faults of the sort could be most readily detected at the Precambric margin, by showing that the overlying sediments had not been affected by the process. No such evidence has yet been forthcoming so far as the writer is aware. Yet there does seem to be evidence of at least some Precambric faulting.

In the eastern Adirondacks, where diabase dikes abound, it is a frequent experience to find them faulted. Often the same dike will be faulted more than once within comparatively small distance. The recognizable faults of this sort are usually of very

[1]Folds of this sort are shown on most of Brainard and Seeley's excellent sketch maps of bits of the Champlain region. See for example Am. Mus. Nat. Hist. Bul. 8:309-11, and Am. Geol., November 1888, p.326.

small throw, or at least of small heave, the dikes being shifted laterally a few inches, or a few feet. More rarely the fault is of sufficient dimension to cause the disappearance of the dike on one side, its new position being beyond the limits of the outcrop.

Since these dikes are themselves of late Precambric age, the fact that they are faulted would indicate a very late Precambric age for the faulting, provided it is Precambric at all. The only evidence of such age is the fact that the later faults, so far as they have been made out, are less numerous and of larger throw. While this is suggestive, it is but slender evidence for making such a discrimination.

As will shortly be shown, joints abound in the Precambric rocks. In numerous instances evidence of vertical slipping along these joints is forthcoming, the immediate rocks being much crushed and sheared, and the planes of slip thoroughly slickensided. Excellent illustrations may be found in the numerous rock cuts along the railroad between Saranac Inn and Floodwood, in Franklin county. The anorthosite is seen to be locally much shattered, abundant joints dividing it into parallel sheets of a thickness of from 2 inches to 4 inches, the rock material much crushed and sheared and the sheets slickensided on both surfaces. The whole zone so affected varies from a few feet to a few yards in breadth, grading off into the normal rock. The frequency of the phenomenon in these excellent exposures suggests that it can hardly be local, and that the fact that it has not been more widely noted may likely be owing to the general poor and unsatisfactory character of the usual exposures in the woods. That, in other words, it is a common occurrence.

Here again the evidence that the faulting may be of Precambric age is merely the difference in character. The Paleozoic faults are fewer and of large throw, and so far as noted do not consist of numerous small slips along closely recurring joint planes, with the production of a multitude of slickensided surfaces. Here again the evidence is far from conclusive. There is however a system of joints in the Precambric rocks which antedates the Paleozoic, since there are more joint systems in the former than in the latter rocks. If it could be demonstrated that the system of joints along which this faulting took place was

formed in Precambric times, the case for the age of the faults would be made out, but this has not yet been successfully done.

Kemp has described three diabase dikes cutting the ore body in the Hammondville iron mines, which he says fault the ore, raising it about 15 feet in each case.[1] The dikes appear not to be faulted. If this be true, the faulting could hardly have been later than the time of dike extrusion. A later fault might, it is true, have paralleled the dike, but that this was the case ought to be readily made out in the exposure. This would seem therefore to be a veritable instance of Precambric faulting.

The older Precambric dikes of the region, more specially the granite and pegmatite veins, are not infrequently found faulted repeatedly and in small amounts, as the diabase dikes are [pl. 11]. Precise evidence of the date of faulting is equally lacking here.

On the whole then it is to be said that, while demonstrative evidence of Precambric faulting to any special extent has not been forthcoming, it is nevertheless quite probable that such was the case, the faulting having occurred in rather late Precambric time, when, owing to the long continued surface erosion, the originally deeply buried rocks had been transferred from the deeper zone of flow to the superficial zone of fracture.

Paleozoic faults. As such may be classed in all probability all faults found in the Paleozoic rocks and many of those in the Precambric. Faulting may well have been initiated in the region at the time of the uplift which terminated Lower Siluric deposition, and which was most marked on the east, being there accompanied by some considerable disturbance of the rocks. The great earth disturbances which prevailed in the Appalachian zone toward the close of the Paleozoic would seem more likely to have brought about the major faulting of the region. To the east and south of the district there was a time of disturbance, resulting in prolific faulting, in the Mesozoic; but, if the region in question was also affected, the results can not be discriminated from those produced in the Paleozoic. However, the Champlain and Mohawk faults are of a different type from those which abound in the Newark Mesozoic of New England and the Middle Atlantic states, which is evidence against their being classed together.

[1] U. S. Geol. Sur. Bul. 107, p.40.

Plate 11

Faulted granite dike, near Westminster park, Wells island

In the eastern Adirondacks there is some evidence of yet more recent faulting, which may have utilized the already formed fault lines, or constructed new ones, the former seeming the more probable supposition, though it is in general impossible to say which was the case. So far as known to the writer, the evidence for this later faulting is topographic simply, certain prominent fault scarps being difficult of explanation except on this assumption.

These Paleozoic faults are for the most part readily made out in the marginal belts of Paleozoic rocks of the Champlain and Mohawk valleys. They are not so readily discoverable on the north, owing to the very low northward dip of the Potsdam and Beekmantown formations there, the great thickness of both these formations and the northerly slope of the surface in the same direction as the rock dip, giving them great breadth of outcrop; while their various beds are so similar lithologically and so unfossiliferous that precise horizons are not to be made out, in a district of such scanty outcrops. Enough evidence can be obtained however to show that the faults do occur, and that the conditions are quite like those on the south side of the region. The strong probability is that the faults, or rather the faulting, extend clear across the region. Evidence of their presence is frequently forthcoming in the Precambric areas, but in these it will require the closest sort of areal work to disclose and to map them accurately.

Faults most abound and attain greatest magnitude along the eastern border of the region. Thence westward they diminish in number and in importance, though large faults occur as far west as Little Falls in the Mohawk region, and at Potsdam on the north, and small ones, at least, are found still farther west.

The greater breaks of the region are meridional, trending from a north-south to a northeast-southwest direction. They therefore rudely parallel the strike of the Paleozoic rocks in the Champlain region, while in the Mohawk region, and on the north, they cut it at a high angle, forming what are known as dip faults, the others being called strike faults [fig. 3, 4]. The large majority of them downthrow to the east and with their rude parallelism divide the region into a series of strips, or slices, this slicing apparently characterizing the bulk of the Adirondack region.

In addition to these greater, meridional faults, differential slipping in the fault strips has resulted in the production of a multitude of cross faults, trending away from the greater ones at all angles, downthrowing now to one side and now to the other, and thus dividing the strips into a number, often a large number, of blocks of varying size and shape, producing great confusion in the stratigraphy and tending to disguise the larger features of the region. These are mostly a feature of the Champlain region and have not the persistence westward of the meridional breaks.[1] As a general rule, they have a somewhat east and west trend but with wide variation in direction. They downthrow now to the north and now to the south, with frequent production of small sunken blocks, downthrown on both the bordering faults. They are in general dip faults, shifting the rocks along the strike, while the large strike faults are apt to cause disappearance of a considerable part of the rock section of the district on the two sides of the fault [fig. 3, 4]. Thus along the great Tracy brook fault, in Chazy township, the entire Beekmantown formation is faulted out, bringing the Chazy and Potsdam together on opposite sides of the fault. A small portion of the course of this fault is shown on the accompanying map [pl. 12]. Just within the map limits its course is more nearly northeasterly than is usual with the great faults and more nearly so than is the case with most of the course of this special fault. About 1 mile to the southeast a parallel fault is seen, and the strip which intervenes between the two is intricately cut up by a number of cross faults, much more so than is true of the district adjoining the strip on either side. Along this pair of faults the entire Beekmantown formation, at least 1500 and likely 1800 feet in thickness, is faulted out, together with an unknown thickness of the Potsdam, from 100 feet to 300 feet at least, and a portion of the Chazy, so that the throw of the fault is 2000 feet or more. It is not a true strike fault, since the dips hereabout are swerving from an easterly, to a northeasterly or northerly direction, but they are so low that the general effect of disappearance of a certain thickness of strata from the

[1]The Mohawk valley faults and some of the larger Champlain faults are well shown on the large geologic maps of the State. The two large scale maps of portions of Clinton county [pl. 12, 13] better illustrate the general character of the faulting in the Champlain district.

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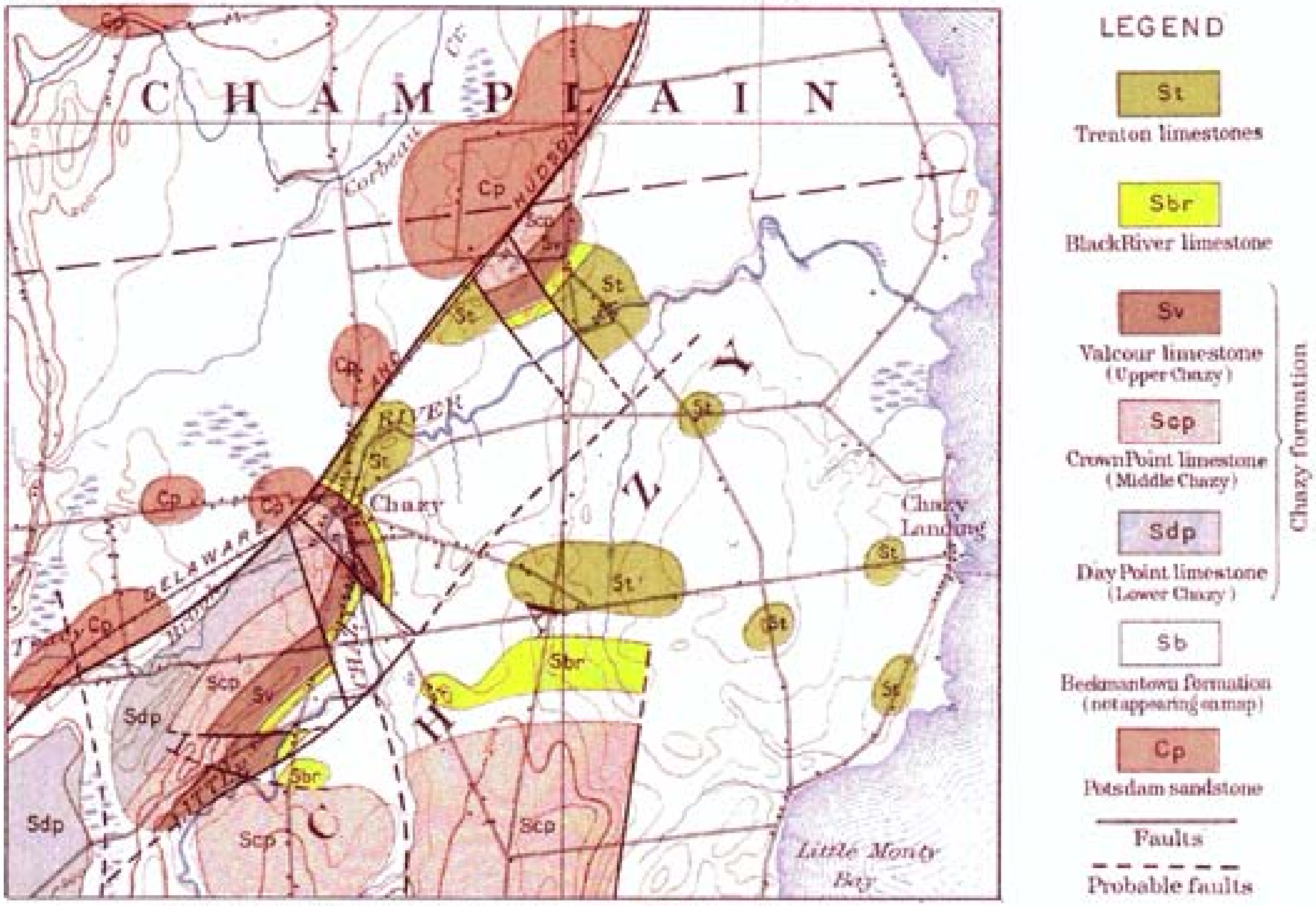


OUTCROP MAP OF A PORTION OF THE TOWNS OF
CHAZY AND CHAMPLAIN, CLINTON COUNTY,
SHOWING THE FAULTS, SO FAR AS THEY HAVE BEEN LOCATED
by H. P. Cushing
1904.

Scale $\frac{1}{62500}$

½ 0 1 2 3 Miles

Contour Interval 20 feet

Datum is mean Sea level

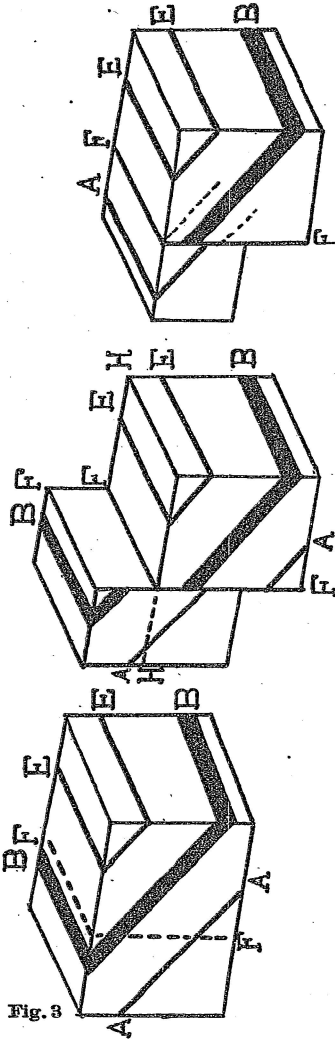


Fig. 3

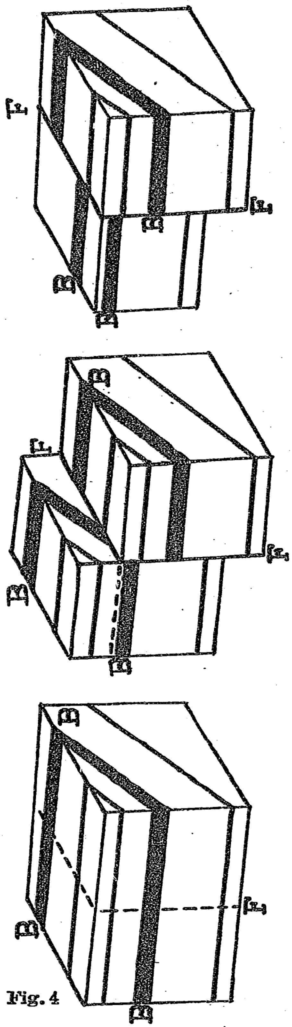
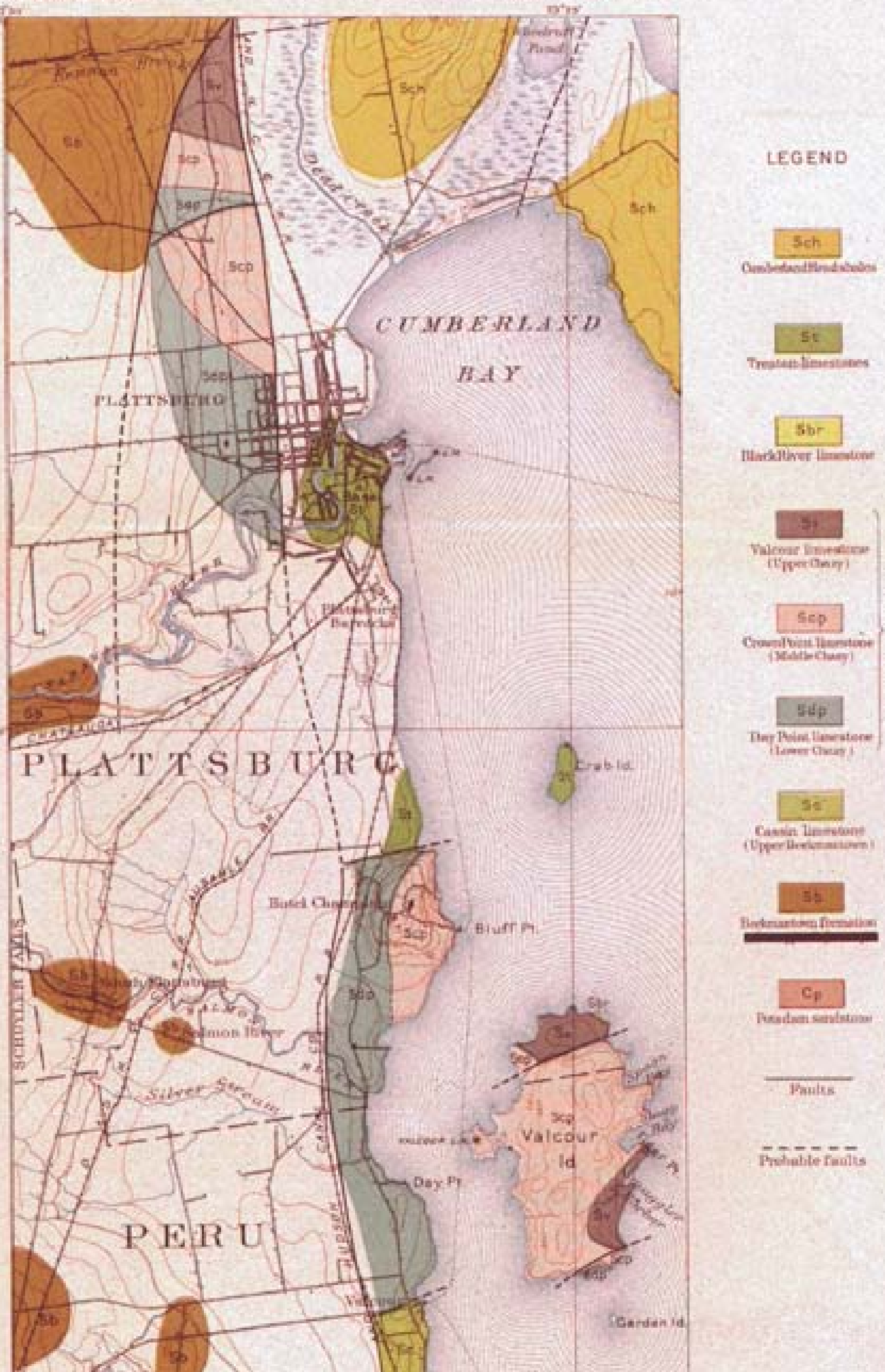


Fig. 4

Figure 3 illustrating a strike, and figure 4 a dip fault. FF is the fault plane, AA, BB, and EE indicate the dipping rock layers. In the former figure the fault plane cuts the surface parallel to the strike, causing a strike fault, in the latter the strike is cut at right angles, producing a dip fault. On the left the unfaulted block is shown, with the position of the fault dotted. In the center the conditions prevailing shortly after completion of the faulting are shown, the downthrow block on the right, and with the prominent fault scarp. On the right the conditions prevailing after sufficient time has elapsed for wearing away the upthrow block down to the level of the other side, or rather for wearing the two sides down to a uniform level, are indicated, this being approximately the condition of most of the faults of the region at the present time. In the strike fault this results in the entire disappearance from the surface of the stratum BB, in the vicinity of the fault, the actual thickness of rock so disappearing being comprised in the space between the dotted lines on either side of BB. By varying the amounts of hade and dip, or their directions, repetition of strata at the surface, instead of disappearance, may result. In the dip fault the effect is to shift the outcrop of a given stratum, so that in an old fault, the surface having been worn down, the ends are shifted forward or back, as the case may be, on opposite sides of the fault, as BB is shifted in the diagram. The amount of this shifting increases with increased throw of the fault, and diminishes with increased dip of the rocks. Few faults meet these conditions of correspondence with dip or strike direction exactly, but many make such slight angles with these directions that they are practically fulfilled.

surface is similar. The small fault blocks in the intervening strip have been updragged by the faulting, giving them a pronounced dip, in general 10° or more, away from the fault plane toward the southeast. Hence the faults that cross the strip are quite typical dip faults, and the lateral shifting of corresponding beds on the two sides of a fault is plainly brought out on the map. Owing to the steep dip, the more resistant rock layers involved appear as low, sharp backed ridges, and the lateral shifting of these, as a fault is crossed, is a prominent, minor feature of the topography. In the most northerly pair of these faults shown on the map, the north one throws to the north and the south one to the south, so that the middle block has been upthrown between the two others. Just the reverse is true with the pair just south of Chazy village, the middle block having been downthrown between the two adjoining blocks. On the east and west edges of the map faults are not indicated simply because outcrops are not sufficiently numerous, or sufficiently definite, to permit of their location. That they are there is quite certain.

Plate 13 shows the faults in a portion of Plattsburg and Peru townships, so far as the outcrops will admit their being located. One very extensive fault of the meridional class, the Plattsburg fault, runs across the map limits from north to south, exposing Beekmantown rocks constantly on the west side and either Chazy or Trenton on the other. The throw of the fault causes the disappearance of the major part of the Beekmantown formation and may be safely set down as at least 1000 feet. Toward the north the throw diminishes, and another great fault develops, the Beekmantown fault, the two coalescing at the north limits of the map and extending on beyond as a single fault of very large throw. Between the two a wedge of Chazy is brought up, with Beekmantown rocks on one side and high Trenton on the other. At the point of junction the Chazy is pinched out and the Beekmantown and Trenton rocks adjoin across the fault. There are two cross faults in this Chazy wedge, two on Valcour island, one on the mainland at Valcour and another just north of Bluff point, as well as several small ones in the shales on Cumberland head, and one on the south edge of the map at Lapham, which brings up the Potsdam against the Beekmantown. Lack of outcrops prevents the location of others.



OUTCROP MAP OF A PORTION OF THE TOWNS OF PLATTSBURG AND PERU, CLINTON COUNTY,
SHOWING THE FAULTS, SO FAR AS THEY HAVE BEEN LOCATED
by H. P. Cushing
1904.

Contour Interval 20 feet

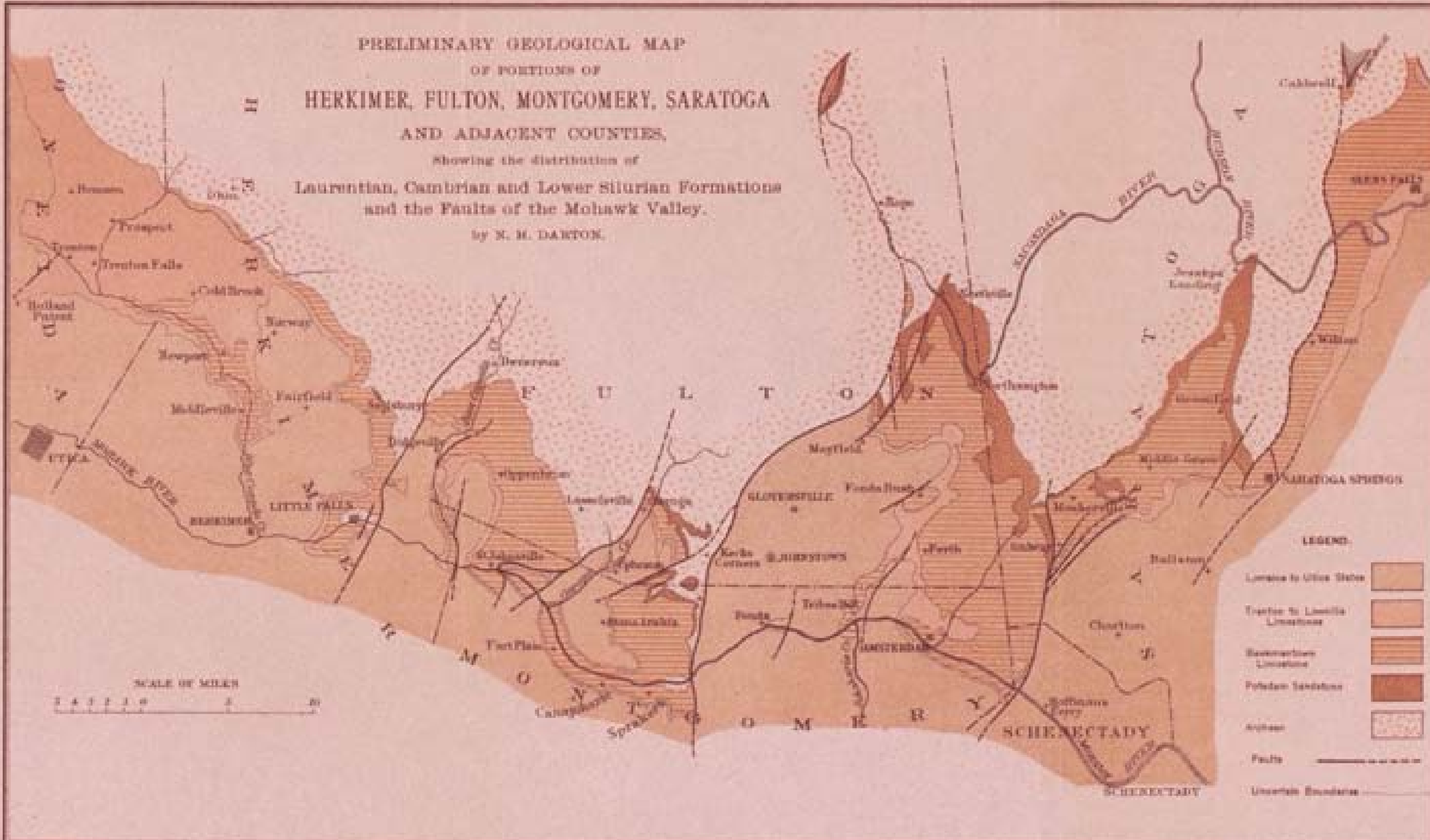
Such conditions everywhere characterize the country along Lake Champlain. Wherever any bit of it has been mapped in detail, one or more faults are sure to be disclosed. They constitute the most prominent and characteristic structural feature of the region.

The faults of the Mohawk valley have been most carefully studied and described by Darton.[1] They are inferior to the greater Champlain faults in number and in size, and the numerous cross faults which characterize that region are less manifest or are lacking here, the faults all having a north to northeast trend, with rude parallelism. Four large faults only, cross the Mohawk valley, the Hoffman, Noses, St Johnsville and Little Falls faults, [pl. 14] though there are several minor ones of less magnitude and extent. Others occur to the northeastward in the Saratoga region, and there must be still others which remain yet undiscovered.

None of these faults have been traced to any distance on the south side of the Mohawk valley, and it is not certain whether they disappear there, owing to dying out, whether they are there but are difficult to trace, owing to unfavorable conditions, or whether they apparently disappear because the overlying Upper Siluric and Devonic rocks were not affected by them. The matter is of importance as giving evidence of the date at which the faulting took place. So far no rocks younger than the Utica and Lorraine shales are known to be involved. If it could be shown that the younger rocks to the south of the valley were also affected, the probability of their Carboniferous age would be much strengthened, or at least any correlation of their date with that of the Taconic disturbance would be rendered impossible.

The only one of these great Mohawk faults with which the writer is on terms of intimacy is the Little Falls fault. With the remainder he has but passing acquaintance. According to Darton all are normal faults with nearly vertical hade, and all downthrow to the east, with the single exception of the comparatively small Dolgeville fault. The throw of the Little Falls fault, where it crosses the Mohawk, is not far from 800 feet, and it maintains approximately the same throw for several miles to the northward. The St Johnsville fault has branched and is fast diminishing in

[1] 14th An. Rep't State Geol. 1894. p.33–54.



Reprinted with slight change from 14 Rep. State Geologist. 1894.

throw near the river, but it increases rapidly northward, Utica shale on the east side adjoining Precambric rock on the other, so that the throw there would seem of equal magnitude with that of the Little Falls fault. The Noses fault involves the entire thickness of the Beekmantown and Trenton formations, the latter only 17 feet thick here, together with an unknown amount of the Utica. The two former aggregate 500 feet, so that a minimum value is thus given, to which must be added the thickness of Utica involved. According to Prosser the Hoffman fault throws out the entire Utica and Trenton and some of the Beekmantown, so that its throw is just about 1600 feet.[1] It is, then, the greatest of the Mohawk faults, as it is also the most easterly.

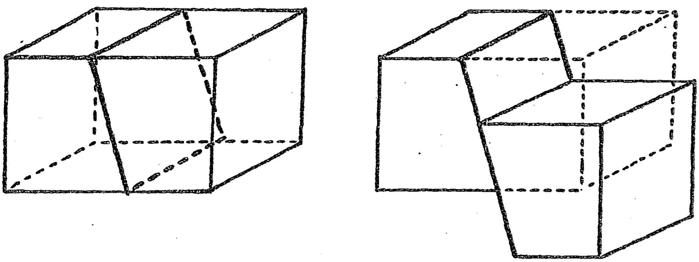


Fig. 5 To illustrate extension owing to normal faulting. First, the unfaulted block is shown with the position of the fault plane, second, the block after faulting, with the original position dotted. The lateral extension, or heave, is manifest. The hade of the fault is 15° and the lateral extension about one fourth of the vertical displacement.

This whole faulted district closely adjoins on the west the district of Appalachian folding. This is a region of sharply compressed rocks, producing folding and thrust faulting. The region under consideration was but slightly affected by these forces, thrust faults being absent and folds present only in the most minor degree. Normal faults are however abundant, in fact are present in both districts. But normal faulting implies surface tension instead of compression, since, except in cases where the hade is absolutely vertical, the rocks have greater lateral extent after the faulting than before [fig. 5]. Since absolutely vertical faults are exceptional, much normal faulting in a district of parallel faults must produce a respectable amount of surface extension. The period of tension would seem to have followed that

[1] N. Y. State Mus. Bul. 34, p.476.

of compression, as is apt to be the case, and this also argues for the late Paleozoic date of the faulting.

Joints

All the rocks of the region are cut by joints, but they are specially abundant in the Precambric rocks. Since joints can be formed only in the zone of fracture, their development in these rocks must have been long subsequent to the formation of folds and of foliation, during which interval the rocks had been approaching the surface because of wearing away of what was above. The joints which are found in the Precambric rocks and not in the overlying paleozoics must be of Precambric age.

Joints may be produced either by compression or by tension. Those of the latter sort are usually vertical or nearly so, while those of the former may be either vertical or inclined. The simplest case of tension jointing is the production of columnar joint cracks in igneous rocks owing to contraction on cooling. Some of the joints of the dikes of the region are of this class, it being the invariable experience that they are more excessively jointed than are the inclosing rocks. The solidifying and cooling of the great igneous masses of the region, however, took place at such great depths as to be below the zone of fracture, and hence they lack joints of this character, being neither more nor less jointed than are the neighboring gneisses.

Tension joints may also be produced by the desiccation of marine sediments underground, and this cause may have operated somewhat in the production of joints in the Paleozoic rocks, though it is doubtful.

Another very likely cause of the production of tension joints is the slow reduction of temperature brought about in rock masses as they approach the surface because of the slow removal by erosion of the overlying rocks. Though the process is an exceedingly slow one, and the changes of temperature involved are not large, yet, considering the great areal extent of the rocks concerned, the necessary contraction would seem considerable, and likely to much exceed the elastic limit of the rocks.

Where rocks are folded in a complex manner, as is usually the case, torsional effects are sure to be produced, which result in the production of two sets of joints, one running parallel to the axes of the major, and the other to the axes of the minor folds.

Compression of rocks in the zone of fracture may give rise to jointing which follows the shearing planes. There would be two different joint sets, which would cut the surface parallel to each other. Such joints would be inclined instead of vertical, the amount of inclination depending on how largely the shear was determined in direction by preexisting planes of weakness, such as bedding or foliation planes. In simple folding both sets of such joints would be parallel with the strike of the beds, one dipping with, and one against them.

The Adirondack Precambric rocks are much jointed. It is however a difficult region in which to obtain accurate measurements of the hade of the joints, though observations on the strike are easily obtained.[1] Moreover, in much of the district the rocks are igneous and poorly foliated, baffling any efforts to determine the structural significance of the joints. The writer's observations have been mainly made in such districts and are not yet sufficiently extended and worked out. Certain things are however clear.

The Precambric rocks are much more conspicuously jointed than are the overlying paleozoics, implying a time of joint formation prior to the deposition of the latter.

Joints are not equally conspicuous in all of the Precambric rocks, being least prominent in the limestones, and most so in the great igneous masses, implying some joint formation while the rocks were at sufficient depth to render the weak limestones somewhat plastic, though the igneous rocks were thoroughly rigid.

Four sets of joints are usually to be made out in the Precambric rocks, though all four are seldom present in any given exposure. Though varying considerably in direction from place to place, they can be apparently referred to two main sets, the one consisting of a pair of north-south and east-west joints and the other of a pair of northeast and northwest joints, both sets swerving in direction through 15° or 20°. In some exposures one set is the more prominent, in some the other set; in many at least three of the four show, and not infrequently all four. The north and east joints are usually vertical, or nearly so, while the others frequently show a greater hade. Not uncommonly, specially in the

[1] As in the case of a fault, the hade is the angle of inclination from the vertical.

great igneous masses, a nearly horizontal set also appears, but this is more intermittent and less regular than the others.

Since the usual foliation strikes of the region are either to the northeast or to the northwest, it is likely that the inclined joints in those directions represent compression joints in the shearing planes, these being more or less controlled by the foliation. An instance of the sort is illustrated in plate 15. The cliff there shown is a joint cliff, with a n. 50° w. direction, an important joint direction in the vicinity. Two sets of inclined joints cut the face of the cliff, both of which have a strike of n. 30° e. The one has a fairly uniform hade of 35° to the northwest, while the other is much more irregular, often swerving into a horizontal position, but in general hading to the southeast. The rock is augite syenite, with a very rude and imperfect foliation, which strikes about n. 40° e., closely approximating the strike of the joints. At the right of the view another joint set appears with a n. 70° e. strike and a hade of 15° to the south, and there is yet another nearly vertical set, not appearing in the view, which has a n. 20° w. strike. It would seem very likely here that the n. 30° e. joints are compression joints, produced in the shearing planes.

Such instances as the above are rather exceptional, however, and the usual, nearly vertical joints which prevail throughout the region have not yet been successfully classified.[1] That at least an east-west system had been developed in Precambric times is indicated by the prevalence of that trend in the diabase dikes. They vary from it through 20° or 30° both to the north and south, but within those limits have it so uniformly as to indicate not only the presence of a fissure system with this trend, but also that this set constituted the line of least resistance to the upward movement of the molten rock. This might have been because this was the only, or the best developed set, but more likely the use of it to the exclusion of other sets was determined by the direction of the side pressure which prevailed at the time.

That minor faulting has often occurred along these joints has already been set forth. It has not yet been determined whether

[1] Such for example as the n. 50° w. series of plate 15, well shown also in plate 16, a nearly vertical set which is quite persistent over a very large area in the mid-Adirondack region.

Plate 15

Cliff at southwest end of Bluff island, Big Tupper lake, showing joints, the cliff face itself being along a n. 50° w. joint

this slip faulting is of the normal or reverse type, that is, whether it took place under conditions of tension or of compression. But the whole aspect of the exposures indicates the action of compressive forces. The best localities for observing the conditions are in the rock cuts along the New York Central and Hudson River Railroad west of Saranac Inn station. All of these show the anorthosite to have been much shattered and sheared, with alteration of the feldspar to saussurite where the action has been most violent. There are four main sets of joints shown in the exposures: a nearly vertical n. 50° w. set, the steadiest and most persistent of all; a nearly vertical n. 80° e. set; a somewhat erratic set, shifting from n. 45° e. to n. 15° e. and not vertical; and a n. 20° w. set, often with a hade as high as 40°. The two latter are the ones which show shearing and slickensiding, and more specially the last one. The shearing planes are closely spaced, dividing the rock into very small blocks, and the minerals are much broken and brecciated. Both these sets appear to be compression joints, representing likely two different periods of compression, and the effect of the shearing would be much more likely to produce compression faulting than tension faulting. The brecciated rock recalls other brecciated strips of the region, notably those described by Kemp from Hammondville, Essex co.[1] These breccias sometimes have a chloritic matrix, but more often one in which quartz and chalcedony predominate and form hard, resistant rocks, so different from the rather loose masses of fault rock which characterize the Paleozoic fault planes of the region that they would seem unquestionably to be much older. That they mark lines of faulting is certain, and the Precambric age of this faulting would seem beyond dispute.

The Paleozoic rocks are invariably jointed, but in general but two sets are to be made out, they being vertical and at right angles to each other. They show a somewhat varying direction, but usually the more prominent set has a north-south trend, with the minor one running east-west. They are most irregular and least clean cut in the massive Potsdam and Beekmantown beds. They have approximately the direction of two of the

[1] 13th An. Rep't State Geologist, 1893. p.456.

sets in the Precambric rocks, but, because they appear less well marked, some hesitancy is felt in ascribing both to a single time of joint formation, specially in view of the evidence for the prior existence of at least an east-west set in the Precambric rocks. It is inferred rather that the coincidence in direction is merely a coincidence.

In the shaly rocks of the Cumberland head series, in the vicinity of Lake Champlain, the stresses which accompanied the folding of the district to the eastward were sufficiently felt to produce cleavage in the weak shales, though the more massive limestones and sandstones beneath were not affected. These shales are found cut by closely parallel cracks with hades of from 30° to 60°. The beds lie nearly horizontally, and this cleavage angle indicates rather a formation of fissility along the shearing planes than a true vertical cleavage in the compression plane. Sharply cut, vertical joints are also present, often in three directions. While the writer has never observed a like structure in any of the Champlain Utica which he has seen, yet the Utica always shows more indications of compressive disturbance, so far as folding is concerned, than any of the remaining Paleozoic rocks of the region. The explanation is undoubtedly to be found in the weak nature of the rocks as compared with the massive, resistant limestones and sandstones beneath, so that folding and shearing were produced in them by forces insufficient to affect the others correspondingly.

TOPOGRAPHY

Introduction

The topography of any old land area is a resultant of the joint action of two great sets of processes. Arising from beneath sea level with the comparatively smooth surface which it possesses because of the rather uniform deposit of sediments on it, it becomes at once subject to the erosive processes which hold sway on all land surfaces, in which atmospheric and aqueous agencies act jointly, but in which running water plays the major role. From time to time it falls under the influence of forces such as that which originally brought it above the sea level, forces originating in the earth's interior in ways not well understood. These vary its altitude with respect to that

level. The forces of erosion work incessantly and according to stereotyped methods, but cease their activity at sea level, hence tend to wear down the lands to a gently sloping surface, rising inland with recession from the shore line. The longer these agents are permitted to work at this task, without interruption from the other set of forces, the larger the proportion of the whole task which will be accomplished. The streams will progressively cut their valleys down to this slope, or grade, after which the work consists mainly in valley widening, bringing a steadily greater amount of the region down to the new level, with a constantly diminishing portion remaining at the old. During the progress of the work a varied topography will be produced, depending on a host of minor factors, rock arrangement and rock resistance being the two most important. The weak rocks will yield most quickly, and many of the streams will adjust themselves to these weak rock belts. The more resistant rocks will persist longer at the old levels, hence tending to become stream divides. The weak belts may be owing to weak rocks or to structural lines of weakness. The rock dip is a most important matter in determining the character of the valleys and uplands. Where it is gentle, flat topped divides and a tendency to radial valleys result. Where it is steep, parallel valleys and sharp backed ridges are produced.

Given sufficient time, the resistant rocks slowly reach the lower level, and the surface becomes comparatively smooth, the interstream areas having low, gentle slopes, with perhaps here and there a low hill or ridge of extraresistant material. Beginning as a plain, the district reappears as a plain, though less smooth than before. Such an erosion surface is known as a peneplain.

If now this process of wear is interrupted at any stage by an oscillation which changes the relative level of land and sea, the grade of the streams is altered, and the whole erosion process must recommence its work with reference to this new grade. If the movement be an upward one, the streams at once commence the task of cutting down the region to this new level, leaving their old task in the condition in which the beginning upward movement found it. Such portion of the region as had been worn down to grade, will carry this evidence of graded

condition upward with it to the new level, where it will persist for a considerable time and furnish evidence of a former graded condition at the lower level, as well as that the level has since been uplifted; its altitude above the new grade which the streams reach will also give the vertical amount of the uplift for the locality.

Prepotsdam topography

During the long existence of the Adirondack region as a land area, it has twice remained at a given level for a sufficient length of time to permit the reduction of almost its entire surface to the graded condition. The first occasion was in Prepostdam times, and the comparatively smooth surface on which that and the succeeding deposits were laid down, as shown on all sides of the region wherever this surface can be seen passing beneath the Paleozoic rocks, is the result. At the beginning of Potsdam time the district seems to have presented the aspect of a low, irregular dome, whose slopes were the gentle ones of the stream grades, and whose longer axis, or main watershed, extended across the region in a southeasterly direction, along a line running from a little north of Watertown to a little south of Albany, and also extended northwesterly into Canada. The streams drained away from it in all directions, but principally to the northeast and southwest. This axis does not divide the present Adirondack region into halves, but lies well toward its southwestern border, so that, at the commencement of Potsdam time, the sea was close at hand on the northeast Adirondack margin, but was many miles distant from that on the southwest; consequently the depression carried the one area below sea level, while the other still continued as a land area. This effect was accentuated by the more rapid subsidence on the northeast. Thus the sands, carried down by the streams and washed about by the waves, are now found only on one side of the district; on the other they did not reach the region, and now lie miles away from its margin, buried deep under newer deposits.

The surface covered by the Potsdam deposits on the north and east sides of the district, is found to be much rougher than that on the southwest, which remained unsubmerged during this time and was not reached by the sea till the following Beekmantown, or Trenton; and it is thought reasonable to suppose that this

greater smoothness is owing principally to this added length of time during which it was undergoing wear. Its irregularities are comparatively few and small; it seems a quite typical peneplain. On the north the irregularities are many and often considerable; are the rule rather than the exception. The surface is quite hummocky and hilly, and the contact line an irregular one. The supposed evidence is perhaps exaggerated in importance, owing to the possibility of undetected faults in certain localities, but is abundant even should all doubtful evidence be eliminated. It does however seem to be true that the irregularities are mostly of a minor order of magnitude, so that, when the tremendous thickness of rock material which was removed in this Precambric interval is taken into account, with the several uplifts, and the quite respectable altitude at times which are thus indicated, the surprise is not that the surface is so rough, but that it is not vastly rougher. Maximum differences of level of but a few hundred feet are all that are involved, and these comparatively seldom. Whether the surface were not sufficiently smooth to be worthy of the name peneplain, is merely a matter of the personal conception of such a surface which different individuals may hold.

The writer has shown that, in the Little Falls region, the present inclination of this old surface is about 100 feet per mile toward the south. The Beekmantown and Trenton rocks which rest on it have a present dip in the same direction of about 70 feet to the mile; whence, if we assume that they were deposited in a horizontal attitude, we obtain a slope of 30 feet to the mile as that which the old surface possessed at the time when the Paleozoic rocks were deposited on it. While this is a gentle slope, it is too steep for one graded by stream action and suggests that the movement of depression itself resulted in some further tilting of the surface. Little or no direct evidence has been obtained in other districts as to its amount of slope.

Paleozoic topography

If the Utica sea overswept the entire region, and all the available evidence seems to indicate that it did, then the region arose from beneath sea level with a smooth, constructive surface whose slopes depended mainly on the character of the uplift. But of this we

are in almost entire ignorance. Nor is there any evidence as to the altitude above sea level given to the region. Subsequent depression and deposit on the southern flanks of the region indicate that much of it had slopes to the south and southwest. How much effect the Taconic uplift may have had on the eastern border is a question, but the possibility of a sagging along the line of the Champlain valley, implying an easterly slope to the eastern part of the region, must be kept in mind. It seems therefore likely that the original character of the region, that is a low, domelike elevation, which slowly sank beneath the encroaching waters of the various early Paleozoic marine invasions, till it was finally overtopped, was renewed by this Postutica uplift, and that the elevation was of the low dome type. Its apex, however, was likely shifted from its former position in the southwest and moved northeastward. The effect of such an uplift would be to increase somewhat the slight initial dip of the sediments outward from the dome in all directions. An alternative view is that the region was merely an extension of the land areas which certainly existed to the north, and to the east during this time, and that it thus sloped, as a whole, to the southwest. In either case drainage would set up on the new surface, and would consist at first principally of streams which flowed down the sloping surfaces, or across the strike of the underlying rock beds. As they cut valleys, tributaries would commence to form, and these would adjust themselves to the rock beds, developing mainly on the weakest and flowing along their strike. With further uplifts, if such occurred, these would tend to extend themselves at the expense of the smaller original streams and lead them off as tributaries to the larger ones.

The Paleozoic cover on the old Precambric floor could not have been thick over the central portion of the region, and would likely have been first cut through there, reaching the resistant Precambric beneath. The area thus exposed would slowly increase in size, faced constantly on all sides by the retreating margins of the overlying rocks. These not only were of unequal resistance, but progressively increase in resistance downwards. Thus the Utica is weaker than the Trenton, that than the Beekmantown, while the Potsdam is most resistant of all to wear.

Consequently each would tend to be stripped away somewhat more rapidly than what lay beneath; thus a terrace would be produced on the bared surface of each more resistant layer as the weaker material above was removed [fig. 6]. This is the general character of topography which is everywhere produced in districts where the rocks lie nearly flat, are of unequal hardness and are undergoing wear. How much progress was made in its production, and how great an area was stripped of its Paleozoic cover during this special interval, it is impossible to say. With the passage of time, and with the increased possibility of wear brought about by later uplifting, the fronts, or infaces, of these

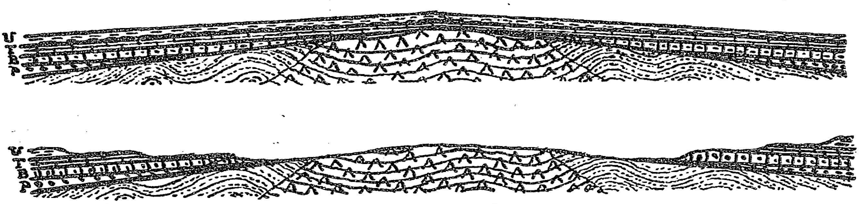


Fig. 6 Diagram to illustrate the condition of the Adirondack region after the Postutica uplift, and the production of terraces by later wear. Vertical scale and dip much exaggerated. P, B, T and U indicate the Potsdam, Beekmantown, Trenton and Utica formations respectively, resting on the Precambric erosion surface. Erosion has not yet cut to sufficient depth to expose the Potsdam, so that its terrace is lacking, and the condition shown is quite like that which is found on the south and west sides of the region today, though in a somewhat modified form on the south. Obviously the depression produced by the opposing slopes of the Precambric floor and the Beekmantown inface, would influence the location of a stream, and the Black river on the west, and certain creeks on the south side of the region, such as Spruce creek in the Little Falls region, are found today occupying precisely that situation.

terraces would steadily retreat away from the center of the region, without however changing their general character. They are today prominent on the south and west sides of the district, where they are accompanied and influenced by the infaces and terraces of the later Paleozoic rocks which there overlie them. On the east and north they are not conspicuous, owing to a variety of causes.

Appalachian uplift

The long period of Paleozoic erosion was terminated by uplift of the region, the movement being merely the local manifestation of the widespread movement of uplift and of dislocation which terminated the Paleozoic era in eastern North America. The forces which folded the region to the eastward, affected the Adirondack district but slightly, and the rocks are not folded.

But in the reaction of the region from compression, tension faulting took place on a large scale, and its eastern portion was sliced by the series of meridional faults which cross it. Since these uniformly downthrow to the east, they produced a steplike topography of eastward facing fault scarps, with intervening terrace platforms. In the Champlain region the faults were numerous, and often of large throw, their combined effect being to cause a rapid drop in altitude eastward, and to produce a depression along the Champlain meridian. But at the same time the region still further east was uplifted, mainly by folding and thrust faulting, thus outlining the Champlain valley as a great structural depression, or trough, closely coinciding in position

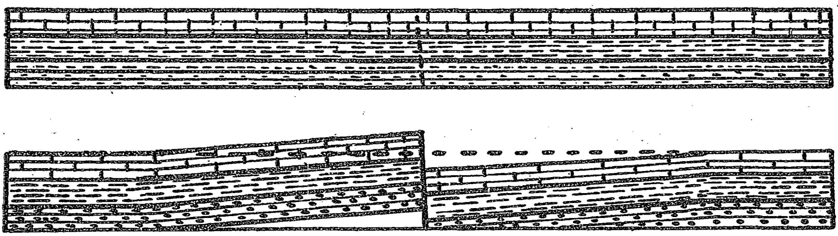


Fig. 7 Diagram of a single normal fault to illustrate the local character of the surface derangement. The rock layers on the upthrow side are given a dip away from, and those on the downthrow side a dip toward the fault plane, but at the ends of the figure the rocks remain as before the faulting.

with the previous depression of the Chazy basin. The region directly to the west of this depressed strip was given considerable altitude by the general elevation, and it seems likely that it formed then, as now, the most elevated portion, with a rapid steplike drop to the east, and a gentle and more even slope toward the west. Passing westward, the faults become much fewer in number, and, while they interrupted the prevailing westerly slope with their scarps, the interruption was but local [fig. 7]. This is well illustrated by the Mohawk valley faults, in whose vicinity a strong increase in the westerly component of the dip is always observable, which flattens back to the normal amount with increasing distance from the fault.

In some few cases trough faulting was brought about by a pair of faults throwing in opposite directions, and depressing the block between. Between the Little Falls and Dolgeville

faults in the Mohawk valley was a block of this sort. Apparently the Paleozoic inlier at Wells, Hamilton co., is preserved in a similar trough. In the Precambric areas to the north, specially in the high Adirondacks, the topography often suggests faulting of this sort. And, as has been shown, cases of this kind are not infrequent between the minor cross faults in the Champlain region.

In addition to the modification in the topography produced by the erection of the fault scarps, the faulting must obviously have affected the drainage. Stream courses would be obstructed by the scarps and the streams turned into parallelism with them, tending to flow along at their bases; and the crushing of the rocks along the fault plane would produce a line of weakness there, which, even after the disappearance of the scarp through wear, would tend to hold the streams there.

Mesozoic base-leveling

This uplift, which terminated the Paleozoic history of the region, obviously renewed the activity of the erosive processes, and the task of cutting down the region toward the new base level thus given it was begun. Though the evidence is not as clear as could be wished, it points to the region having remained at this newly given level for a long time, long enough to permit the wearing down of the major portion to a comparatively even surface at this new stream grade. In other words, it was worn down to a peneplain, above whose general level certain hills of various altitudes arose, none of which exceeded 1000 feet in elevation, which had resisted somewhat the general wearing tendency, mainly because of advantageous situation. The infacing escarpments of the Paleozoic rocks retreated well away toward the margins of the region, till the weak belts reached grade, after which the escarpments would disappear as the stronger rocks slowly came down to the same level; the fault scarps also disappeared, both sides coming down to the general level; the streams which were flowing parallel to the sides of the region, adjusted to the weak rock belts, would accompany these belts in their movement away from the heart of the region; they would also increase in size by the capture of many of the

outflowing streams, leaving only the largest and most advantageously situated of these in their old courses.

It has been shown that the later Mesozoic was a time of widespread base-leveling over much of the eastern United States, notably in the Appalachian region and in southern New England. While subsequent wear has removed much of that old surface, the many fragments that yet remain indicate, by their concordant summit levels and by their level ridge crests, that they are remnants of a former plain; and that it was an erosion plain is shown by the fact that its surface is notably discordant with, or bevels, the rock beds. An extensive erosion plain of the sort can only be produced, on a land surface, at stream grade, and during a protracted period of comparative stability of level.

It has been further shown that this plain has been tipped by subsequent movements, the evidence for which is the present diminution of altitude in certain directions. Thus the uplift of the Cretaceous peneplain of the Appalachians was greatest along a n.n.e.-s.s.w. axis, from which the old surface drops both to the east and to the west. The uplift was also unequal along the axis, being greatest in Virginia and descending both to the north and the south. The peneplain of southern New England, which is supposedly of the same age, is strongly tipped toward the south.

This uplift was followed by another period of comparative stability, during which large progress was made in reducing the surface of these districts to the new base level. This interval was not, however, so protracted as the previous, so that the region was only partially base-leveled. Broad valleys were opened on the weak rock belts, while but little progress was made in the reduction of the resistant rocks, which remain substantially at their previous level, and form today the remnants of the Cretaceous peneplain.[1] The widely opened valley bottoms on the weaker rock belts, with their concordant altitudes when compared with one another, furnish the main evidence for a long stability of the region at this grade.

[1]Campbell has recently urged the presence of a base level intermediate to these two, from evidence obtained in northern Pennsylvania and southern New York. Geol. Soc. Am. Bul. 14:277-96.

This is no longer the grade of the region, a comparatively recent movement having elevated it, and the streams are now busily engaged in the task of getting their beds down to the new grade and of widening their valleys. They are yet far from being thoroughly adjusted to the new conditions.

Peneplains

It would seem inherently probable that the Adirondack region participated in the actions outlined, but several causes conspire to make the evidence less clear than in the other districts mentioned. In the southern and western portions of the region, however, the hilltops do, in general, rise to quite concordant levels, which are wholly independent of the rock attitude and structure, and the inference is irresistible that they rise to the level of an old and comparatively even erosion surface, quite

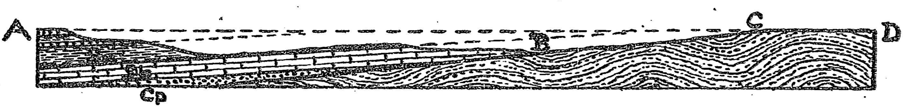


Fig. 8 Somewhat ideal section from north to south across the Mohawk lowland. The Cretaceous peneplain surface extended across the region from A to D. Following the uplift, the intervening region has been worn down, owing to the weak character of the limestones, Sb, and the shales, Su. The harder rocks at A, and from C to D, have resisted wear and remains at the old level. Erosion has not yet reached the horizon of the Potsdam sandstone, Cp. The wearing away of the limestones has bared the underlying Precambric rocks from B to C, exposing the old, Precambric erosion surface, which meets the Cretaceous peneplain at a small angle, which the large vertical exaggeration of the diagram makes altogether too prominent.

Fig. 9 shows the angle drawn to true scale, the upper line representing the CD, and the lower the BC slope.

likely a product of the same great erosion period which elsewhere developed the Cretaceous peneplain. The probability is hightened when it is seen that the prolongation of this surface southward, above the Mohawk lowland, to the plateau of southern New York, finds it in close correspondence with the upland levels there, as if the two were developments of the same great surface [fig.8]. In both districts, too, this surface is now tipped to the west.

This old peneplain is best preserved in Hamilton county, though well marked also in Herkimer and St. Lawrence. On the west and south margins of the region it is replaced by another

erosion surface of different slope and origin. This has its rise in the very resistant character of the Precambric rocks when compared with the overlying paleozoics, specially in districts where the Potsdam sandstone is thin or is absent, as it is on the west and south. During a cycle of wear, these weaker rocks are stripped away from the underlying Precambric, whose old erosion surface thus reappears, and tends to maintain itself for a time, owing to its extraresistant character [fig. 8]. Thus is produced a considerable strip of Precambric rocks on these two sides of the region, with an even hilltop line, which comes to this level, rather than to that of the Cretaceous peneplain. It, however, slowly rises to meet, and insensibly merges into that.

Quite a number of monadnocks, as residual hills which are not worn down to the general peneplain surface are called, exist in the region, their summits reaching a few hundred feet above the general hilltop level. They are not sufficient in number to obscure the general level, though they do somewhat disguise it.

In the same districts the later base level is also indicated by the rather broad valleys and their comparatively uniform levels. It is also observable that, in passing toward the heart of the region, the valleys are deeper cut, in other words, that the vertical interval between the two plains increases, indicating that the Cretaceous peneplain was tipped when elevated, and that the uplift was greatest on the northeast, so that it is now canted considerably to the west and slightly toward the south.

In the eastern Adirondacks the above features can not be satisfactorily made out [pl. 16]. There is little concordance in the summit elevations, so that either the district was not reduced to a Cretaceous peneplain, or else that surface has been dislocated, and given varying altitude, by subsequent movements. Possibly both may be true, and there is some evidence which points to the dislocation having actually taken place.

Recent uplift has affected the entire Adirondack region, in common with a much larger area, and this uplift has been greatest on the northeast. It has amounted to at least 400 feet at the south end of Lake Champlain, and at least 550 feet at the north end, and to 250 feet or more at the east end of Lake Ontario. And these are minimum figures, which must likely be much increased when the entire movement is taken into consideration.

Plate 16

View of the Seward-range from the Hiawatha House, on Stony Creek pond. The summit is 8½ miles distant

It is not certain whether it has ceased or is yet in progress, though the latter is very probable. The streams are working their way down toward the new grade, but have made comparatively slight progress in the task.

Main axis of elevation

The highest elevations in northern New York occur along a line which, commencing at the national boundary on the north, runs south along the line between Clinton and Franklin counties, till it reaches the district of the high peaks in northwest Essex. Here it offsets sharply to the west, into southern Franklin and northern Hamilton counties, then turns again toward the south and runs down through Hamilton, in this part of its course trending about s. 20° w. instead of nearly due south, as at first.[1] In this change of trend a rude parallelism with the folded rocks to the eastward is to be noted, these also swerving toward the west in passing into New York from the Vermont side. This probably implies an interrelationship between the two, at least in so far as the original location of this main axis is concerned.

Along the Hamilton county portion of this main axis are found the greater number of, and the larger of, the monadnocks which protrude above the Cretaceous base level south of the mid-region. They are so numerous that, were this area alone concerned, the Cretaceous base level would be difficult of recognition. Parallel with the eastern edge of this uplift is a rather deep and wide valley, eastward from which the region is much more dissected, and with considerably lower hill altitudes. The features strongly suggest that the eastern face here is along a line of fault.

The abundance of monadnocks in this district would indicate that, during the period of Cretaceous base leveling, the main divide of the southern district must have been hereabout, just as it is now, since the rocks are not more resistant here than elsewhere. They must therefore owe their preservation to favorable position.

Among the high Adirondacks in Essex and Franklin counties the country is still more rugged and uneven than in Hamilton, so

[1]On a small scale these features are well shown on the "Map of New York showing the Surface Configuration and Watersheds," recently published by the State Museum.

much so that no sign of concordance of level is to be noted among the hill summits.

This main axis of elevation is everywhere so pronounced that it would seem that it could hardly be a feature which had outlasted the long period of Cretaceous base leveling, but that its present prominence must be owing to unequal uplifting at the close of this erosion cycle. The considerable deepening of the valleys in passing toward the heart of the region (the broad valleys cut in the succeeding erosion cycle are the ones here concerned) points clearly to greater uplifting along this line. It also seems likely that, in a region of abundant faults such as this is, such an uplift could not fail to cause additional adjustment along the fault planes. Such movements would give varying altitudes to such portion of the area as had been graded during the long erosion period. That many of the tops of the high Adirondacks are true monadnocks, is highly probable. But that the area is entirely composed of monadnocks, and never had any recognizable development of the Cretaceous peneplain on it, is thought to be exceedingly improbable, much more so than the alternative view here presented. And this is emphasized when the rapid drop in altitude to the Champlain valley is taken into account, both its rapidity and its character suggesting rather recent faulting.

On the prolongation northward of this main axis, the same features are illustrated in the Paleozoic rocks, these being found at the highest altitudes along that line, dropping rapidly eastward down the faults and less rapidly, and more regularly westward. This represents the total amount of tipping which they have received in all the movements of the region, but the present prominence of the axis as a topographic feature seems too great to be accounted for otherwise than by a not too remote date for the last differential movement along it. In addition, certain prominent eastward facing cliffs which appear to be fault scarps, are found in the Potsdam country, just as they are in the Precambrian areas, fault scarps which seem to require actual faulting of comparative recency to account for their presence. The evidence, then, seems to point to actual warping of considerable

amount along this axis during the uplift which terminated the Cretaceous erosion cycle, with accompanying downfaulting on the east, giving the fragments of the Cretaceous peneplain varying altitudes and increasing the prominence of the Champlain depression.

Lake belt

In southern Franklin county, nestling in the angle produced by the offset of the main axis of elevation to the west is an area of broad valleys and low ridges in which lakes are more thickly clustered than in any other part of the region, and for which therefore the name "Lake belt" has been suggested, for the lack of a better term. The valley bottoms have the same levels that they have in adjacent districts, but the ridges are low, commonly only 200 feet or 300 feet high, not by any means attaining the levels that they do in the country east, and considerably lower than the summits in the other direction, though the discrepancy is not so pronounced. The relief is in general insignificant. All the ridge summits are well beneath the horizon of the Cretaceous peneplain level.

No cause for this discrepancy is to be found in the character of the underlying rocks. These are anorthosite and syenite for the most part, the most resistant of all the Adirondack rocks. The rocks of the Lake belt are in no sense weaker than in the areas of higher altitude and greater relief adjoining, are in fact stronger than those to the west.

The belt has many features which indicate that the main preglacial drainage systems passed through it; and this would necessarily tend to lower its general level more rapidly than would be the case at a greater distance from the main drainage lines. But the fact that it is sharply separated from the adjacent districts instead of fading into them, with no change in the rock character, and the abundant rock ridges, all of small altitude and none reaching at all nearly the Cretaceous base level, seem to require a structural cause for their explanation; and it is regarded as a probable dropped fault block, the district to the east having been

greatly uplifted as compared with it, that to the west considerably less so. Its own hilltops reach concordant levels, and probably represent the Cretaceous base level, but dropped below its normal altitude.

Faults as topographic features

As has been stated, it is probable that all fault scarps in the region disappeared by being worn down during the Cretaceous base-leveling period. Such wearing down customarily brings different rock masses into juxtaposition on opposite sides of a fault. Any renewed uplifting of the district then tends to cause a reappearance of a scarp along the fault line, owing to the more rapid wearing away of the weaker of the two rocks. The hight that this scarp may attain will have the difference between the old and the new base levels for its maximum value, and the proportion of this actually attained will, other things being equal, depend on the comparative resistances of the two rocks. If one is very strong and the other very weak, relative prominence may be gained, specially in the near vicinity of drainage lines. The weaker rock may be on either the downthrow or the upthrow side, and, according as the first or the second is the case, the scarp will face in its original, or in the opposite direction, in the latter case giving rise to the anomaly of the downthrow side standing at a higher level than the upthrow. In the cases where there is little or no difference in resistance between the rocks on the two sides, there will be no tendency to cause reappearance of a scarp along the fault line.

Furthermore, except in the case of faults which exactly parallel the strike, the surface rock will vary from time to time on the same side of the fault, and with these changes, now on one side and now on the other, the scarp becomes either less or more pronounced than it was before, as the variation diminishes or increases the difference in resistance of the rocks. In the case of dip faults an irregular topography is sure to be produced along the fault, owing to the more frequent passage from one sort of rock to another.

In general, the faults of northern New York show a weaker rock on the downthrow side and hence tend, on uplift, to reproduce a scarp facing in the direction of the original one.

There are however numerous cases where the resistance is practically uniform on both sides.

In the Mohawk valley region there is no evidence of any recent faulting. The faults are quite typical dip faults, in a district of low dip. Since the Paleozoic rocks there, from the Beekmantown to the Utica, are progressively weaker upward and are all weaker than the underlying Precambric, it necessarily follows that the faults everywhere show weaker rock on the downthrow side, except where the same formation occurs on both. Owing to the recent uplift of the region, the scarps are coming into prominence, specially where they are crossed by streams. In fact, the utter independence of the faults shown by the streams here, is one of the strong arguments against any recent movement along the fault planes, and for such present day prominence as they have being wholly due to the recent uplift of the region.

Along the Mohawk the faults show great cliffs facing eastward, the valley widely opened in the weak shales on the downthrow side, while constricted and gorgelike in the resistant Beekmantown or Precambric rocks on the other. Receding from the river, their prominence is at once lost, and the scarp is either not manifest or but feebly marked. Thus the Little Falls fault, a very noted topographic feature at the river crossing, loses this character entirely a short distance south of it and has no great prominence on the north, when the great difference in resistance of the rocks is taken into consideration. Eventually it passes wholly into Precambric territory and can be no longer traced. While this may be because of the dying out of the fault, there is no evidence that this is the case. If, on the south side, the fault could be followed through the Utica shale belt to where the more resistant overlying rocks appear, these would come in first on the downthrow side, with production of a scarp facing west.

In the Paleozoic limestones along Lake Champlain, which have great thickness, but no marked difference in strength, the fault scarps are in no way conspicuous at the present day; in fact, at low altitudes there are none at all. At higher levels, however, they appear. Thus the Tracy brook fault shows no scarp in that part of its course shown on the map [pl. 12], notwithstanding it

has resistant Potsdam on one side as against weak limestones on the other. Farther southwest, however, where it passes into higher ground, the prominent east face of Rand hill is its scarp. So far as these low altitude faults are concerned, they give no evidence of recent faulting.

Some slight relief has been produced along some of the small cross faults, in cases where the dip is fairly high, 10° or more. These are dip faults; and, since the limestones which they cross have slightly variant resisting power, the more massive beds stand slightly above the surface as ridges, and their lateral shifting by the fault is clearly brought out in the topography. The Black river limestone, and some of the beds of the Crown Point division of the Chazy, are the more prominent ridge makers of this type. This topography is very characteristic of the cross-faulted strip shown in plate 12.

The drainage is not so independent of the faults in this district as it is along the Mohawk. Many of the streams follow the fault lines for considerable distances, Tracy brook and the Little Chazy river, as shown in plate 12, for example.

It is however in this eastern district that the evidence of recent faulting is forthcoming. In the rapid rise in altitude from the Champlain level to the main axis of elevation, which is from 25 miles to 30 miles west from the lake only, are many eastward facing cliffs which resemble fault scarps. The larger number of these show equiresistant rock on both sides. Thus there are apparent faults which are wholly in the Potsdam, having that rock on both sides and with no detectable difference in the resistance, which, notwithstanding, present a prominent easterly cliff. Wear, because of renewed uplift, could by no possibility have brought out this topographic relief; and, in the total absence of evidence of any other mode of origin, a belief that they are fault scarps is compelled, necessitating the further belief that they can be no older than the date of uplift of the Cretaceous base level, and may perhaps be younger.

The majority of the supposed faults are in Precambric rocks. In many cases there seems little difference in resisting capacity of the rocks on the two sides, and in certain cases the rock is

identical. There are several cases in which the presence of the scarp can not possibly be owing to differing rock resistance, so that the only element of doubt in the matter concerns the actual existence of the faults. They are very difficult to prove under such circumstances, yet it seems practically certain that they must be there.

North plain

On the north side of the Adirondacks a gently sloping plain extends from the Precambric boundary down toward the St Lawrence. It is warped upward along the north extension of the main axis of elevation, hence has a northerly pitching axis along this line, with northeast and northwest surface slopes away from it. These are but gentle, some 20 feet to 30 feet to the mile. The underlying rocks are the Potsdam and Beekmantown formations, which have a low, northerly dip. This is however considerably greater than the surface slope, amounting to from 100 feet to 200 feet to the mile, so that the rock layers are beveled by the plain surface, progressively higher beds being exposed going north.

The general surface has received a comparatively smooth veneer of glacial deposits, supplemented by the deposits of running and static waters during and after the ice retreat. Low moraines constitute the principal present irregularities. There is no Beekmantown inface, for example, though this may be lacking because of being planed down by the ice sheet. Rock outcrops are so scarce in the region, however, that there is no opportunity to determine whether this is the case, or whether the inface has been buried beneath the drift. The old stream valleys have been filled up, and the streams have since somewhat reexcavated them though, since they have not accurately followed the old channels, they have met rock at small depth in spots where they have missed the track, and this has greatly retarded the reexcavating process. The plain retains approximately its preglacial slope, but its irregularities have disappeared through

blanketing. It lies below the Cretaceous peneplain level, having been worn down below that in the Postcretaceous erosion cycle.

The Precambric boundary presents quite different characters on the north from those seen at the south. It is much more sinuous and much more abrupt. There is no Potsdam inface, and the Precambric rocks are apt to tower somewhat abruptly from 25 feet to 100 feet or more above the Potsdam level. Between these outlying ridges embayments run, carrying the slope of the plain in between the ridges, and in many of these embayments the Potsdam is found, lying between the gneisses of the adjoining ridges. Faulting has undoubtedly played some part, perhaps a major part, in the production of these features, but it does seem quite clear, nevertheless, that the shore had a steeper slope than on the south, and that the surface was much less even.

Northern hills and valleys

The ridges and valleys of a large part of the Adirondack region show a general north-south to northeast-southwest trend, this being more prominently the case in the eastern half of the region. The precise cause for this general trend is not clear. The larger faults have this direction and are undoubtedly influential factors in the topographic control; the strike, both of the foliation and of the Grenville bedding, has often the same direction, and has no doubt its share in determining the topographic alinement; one main joint set has the same trend and may also be a factor; finally, the ice sheet moved over the district with a south to southwest direction; and, though the direction of the basal currents was mainly controlled by the existing topography rather than the topographic trend a result of the ice direction, yet some share in the general shaping of the region must be allotted to it. It seems likely that all these factors have combined in the production of the present trend; but it is as yet wellnigh impossible to determine definitely their relative importance. The frequent independence of this trend shown by the strike naturally suggests that it is of less importance than the others. The prominence of other joint sets, in addition to

those trending with the ridges, indicates that they were not the controlling factor, but that the direction was determined by something else, and, once determined, this joint set becomes of greater importance than the others. By a process of elimination, the faults seem to remain the most probable controlling factors in the original determination of the trend.

The present valleys were excavated below the Cretaceous base level in the Postcretaceous erosion cycle. The comparative weakness of the Grenville rocks determined valley location where they were present in any force, and a respectable number of the valleys of the region are of this origin. They are most numerous in western Essex and St Lawrence counties, being comparatively infrequent elsewhere. There are also many valleys in which one or more small patches of Grenville rocks may be found, surrounded by others of a different nature; and in these it is quite possible that the Grenville patches are merely the final remnants of much larger Grenville masses, which determined the location of the valley and have disappeared in its formation. But even where a very large allowance is made for possible instances of this sort, it yet remains true that Grenville rocks make small show in most of the region, and that the larger number of the valleys can not have been located on Grenville belts; are developed in fact in rocks identical in kind with those which make up the neighboring ridges. To account for these, it seems necessary to invoke some structural cause, and such may be found in belts of rubble rock along the faults, in belts of excessive jointing and slip faulting, and in the location of streams by the original fault scarps; also in the production of actual fault valleys (*Graben*). These are truer in direction than the Grenville belts and best explain the prevalent trend.

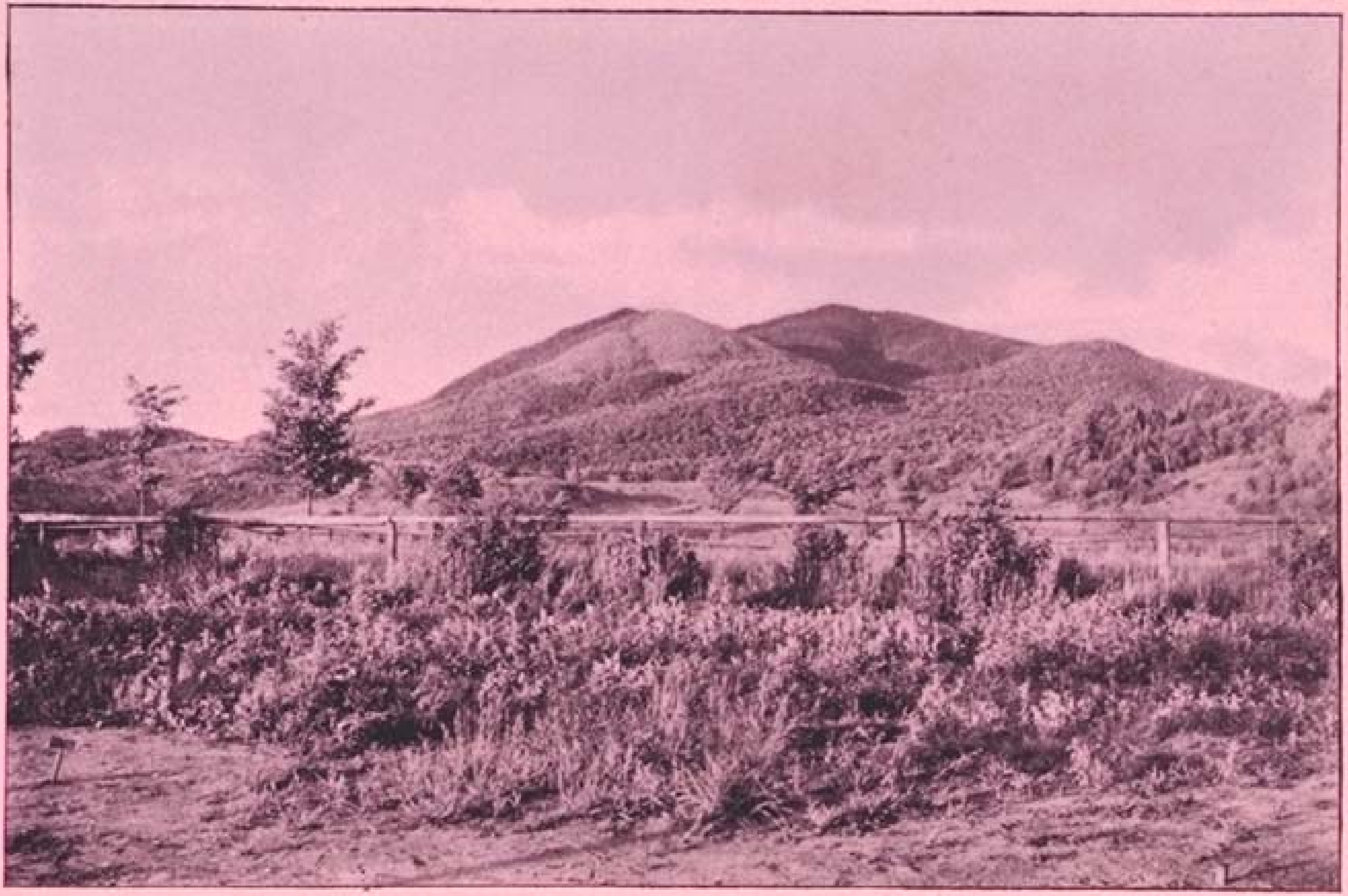
The larger number of the ridges of the northern Adirondacks show a certain type of configuration which calls for explanation. They have a long, gentle, even incline to the northeast, a summit well toward the south end, and a steep back slope, often in part a perpendicular cliff and in general steepest at the top. These features are seen most typically on the smaller ridges, but the larger ridge masses show a tendency to the same type. At the backs of these an amphitheater is apt to be developed, sometimes

of the typical cirque shape, and always strongly suggestive of glacial action [pl. 17]. Precipitous rock cliffs are always a feature on this side, while wholly absent on the gentle north slopes, on which rock outcrops of any sort are infrequent. The writer has often searched the north slope of such a ridge without finding a single satisfactory outcrop, while they are certain to be abundantly found when the summit and back slope are reached.

In the high Adirondacks, in the anorthosite region, these features are not found, the cirques excepted, and these are found along the flanks of the ridges as well as at the back. Stony Creek mountain [pl. 17] is an anorthosite mountain and on the edge of the high peak district, but it exhibits the general features just noted very imperfectly. They are better shown in many of the syenite peaks and in the main seem confined to the ridges of foliated rocks. The syenites always show more foliation than the anorthosites. Yet the writer has been unable to discover any connection between the strike and pitch of the foliation and the trend and pitch of the ridges; and, if any such does exist, it is obscure, though the facts noted above suggest some relationship.

That much of the shaping of the ridges has been done by glacial action seems clear. The northern hills are the ones mainly concerned, those so situated that they would feel the full force of the onset of the southwestwardly moving ice, after its advance, unimpeded by any obstacles, over the plain to the north. It must have impinged heavily on the north slopes of the hills, and the basal currents moving up the intervening valleys must have closely hugged the ridge sides. There would be at first a tendency to wear down all projections, and later to fill up depressions and blanket the slopes with till and moraine stuff. The lee side of the ridge, however, would not be closely enfolded by the ice, so that little smoothing would be done there. In the waning stages of the ice sheet a *bergschrund,* or *crevasse* between the ice and the back slope of the mountain, would be formed, in which a daily variation of the temperature from thawing to freezing would take place during a large part of the year, which would cause a rapid scaling off of the rock along the joints, producing rough, steep cliffs. During the wan-

Plate 17



Stony Creek mountain from Axton, looking east northeast. Distance to the summit $3\frac{1}{4}$ miles. The mountain is not of the typical ridge type though it approximates it. It broadens out on the southwest and sends out two spurs with a deep amphitheater between

ing of the ice sheet or at a somewhat later period, small local glaciers appeared high up on the mountain sides which, grinding away at their beds, with this *bergschrund* action at work on their sides, excavated the amphitheaters. But, while the ridges have thus been ice-sculptured, it is wholly unlikely that they were produced by glacial action. The ice found the ridges and valleys when it entered the region and merely left them somewhat modified. Some of the back slope cliffs strongly suggest fault scarps. One for example, suggests a fault across the ridge crest which has dropped its southern portion and produce the cliff and terrace outline. There is but a single sort of rock in that ridge, a resistant quartz syenite gneiss, so that the topography can not be accounted for by varying rock resistance. The sudden manner in which many of the ridges are chopped off at the south is very indicative of faulting. If faults are present, they are cross faults, since the main ones parallel the ridges. It is an exceedingly difficult matter to determine just how large a share the faults have had in determining the present situation and character of the ridges.

Streams

The working out of the varied history of the Adirondack streams is a matter of the future. No one has yet had opportunity to give the problem the thorough and exhaustive study that it requires. Furthermore, it is a difficult problem, owing to the great age of the land area, the several oscillations of level which it has experienced, the difficulty of determining the controlling factors in the Precambric district, and the many changes produced in the drainage by the action of the ice sheet.[1]

The general drainage of the present day runs radially outward from the main axis of elevation, and in part these streams seem the lineal descendants of the original consequent streams. Since

[1]No attempt will be made in this paper to discuss the Pleistocene history of the region, since little connected work has hitherto been done on it. and because Professor Woodworth is now at work on the problem. Much information may be gained from papers by Brigham and Ogilvie. Geol Soc. Am. Bul. 9:183–210; Jour. Geol. 10:397–412.

a blanket of Paleozoic sediments probably covered the entire region, these original streams soon became superimposed streams, and showed no adjustment to the Precambric rocks which they uncovered in their beds during the stripping away of the Paleozoic cover. The present valleys are largely adjusted to these rocks, and this adjustment has been brought about by the successive uplifts of the region, each new cycle of wear tending to make it more perfect. The adjustment is in part on the weak rock belts and in larger part on the weak rock structures.

The Champlain valley has been shown to be a structural one, and as such to be the inevitable site of a drainage system. The subsequent origin of the Mohawk and Black rivers has also been indicated and had been previously emphasized by Brigham and others. The St Lawrence valley has also the character of a subsequent valley, as was first pointed out by Westgate; but, as it was the site of an old Paleozoic trough of depression and deposit, which seems to have been deepened by subsequent movements, this would appear to have had some share in determining its position. With successive uplifts of the region, the Mohawk and Black river valleys move laterally outward. This is not the case with the Champlain valley.

The outflowing Adirondack streams of the present are thus all tributary to streams which parallel the sides of the region. Those outflowing to the west and south are but the remnants of the consequent streams which continued on in those directions before the development of the Mohawk and Black river valleys, as Brigham pointed out. They rise near the main axis of elevation and flow in valleys cut in its gentle westerly slopes. Beginning at the southwest with West Canada creek, apparently only recently transferred to the Mohawk drainage from the Black, all the westerly streams, the Moose, Beaver, Oswegatchie, Grasse, Raquette, St Regis, Deer, Salmon and Chateaugay rivers, have this general character. All have been affected and modified by the ice sheet; but these modifications are local, and otherwise these streams rise near the main axis of the region and course down its westerly slopes, to the southwest, the west and the northwest. The abrupt

deflection of the Oswegatchie, Grasse, Raquette and St Regis from their normal northwest courses to a northeast direction, so that they flow parallel to the St Lawrence for many miles before emptying into it, is an interesting feature which has not yet been explained, though probably not difficult of explanation when the ground is thoroughly studied. The Oswegatchie emerges on the Precambric rocks of the Frontenac axis, and its behavior is obviously controlled by the topography, as it takes a subsequent course parallel to the ridges. But the other three streams make their bend on the northern Paleozoic plain, and the cause can hardly be a structural one. It must be sought in the Pleistocene features of the region, either this portion of the plain having a general slope to the northeast, owing to unevenness of glacial deposits, or else morainic or beach ridges being the deflecting cause.

The streams of the eastern Adirondacks mostly rise in the neighborhood of the high peaks. The Hudson and Ausable have their head waters in the high passes of that district. The Schroon and Sacandaga head in the ridges east of the main axis. The Saranac, on the north, heads in the Lake belt and is the only one of the principal streams to cross the main axis of elevation, both of its branches so doing. That portion of it which lies west of the axis is separated from the present Raquette and St Regis systems by the most trivial of glacial divides, and undoubtedly drained to the westward formerly. The date of capture by the Saranac is not known. The easterly flowing Adirondack streams have an advantage over those flowing west, owing to their steeper slope, and tend therefore to extend their head waters westward, causing the divide to migrate in that direction, away from the main axis. That the capture occurred in preglacial times seems very probable.

Farther south, in eastern Hamilton county, the main axis is crossed by two broad valleys, one running east from Long lake and the other from Raquette lake. These are however located on weak Grenville belts, on which it was easy for streams, flowing eastward from the main axis, to push their divides westward

across the axis. The modern divides in that region seem of glacial origin, and our present knowledge does not suffice to determine how much of the drainage west of the axis had been captured in preglacial times. That the drainage of the Long lake and Raquette lake valleys went out to the northwest in preglacial times is exceedingly improbable, and it may well have gone eastward to the Hudson.

The fact that the main axis of the region is to so large an extent the modern watershed, is the strongest of the arguments for its prominence having been given to it in comparatively recent times.

The northeastern streams, the Ausable, Saranac, Big Chazy and English rivers, flow in general northeast courses away from the main axis. Faults control them somewhat, and here the direction of the main faults is also that of the consequent stream flow. The upper Ausable and Saranac are, in part at least, controlled by faults. In their lower courses all cut across the strike of the Paleozoic rocks.

It is in the southeastern part of the region that the streams show the most marked adaptation to the structures, as was noted by Brigham on the publication of the first topographic sheets of the region.[1] The main streams here have n. to n.n.e. or s. to s.s.w. courses and receive their main tributaries from the west. Such Grenville belts as occur trend with the tributaries rather than with the main streams, and the determining cause of location is obviously a structural one. Ogilvie argues that the faulting was accompanied by block tilting toward the east, that the main drainage lines are located along the faults, and that the tributaries on opposite sides work against an abrupt fault cliff on the one hand or down a gently tilted slope on the other; that those down the slope have a conspicuous advantage and have extended their courses much farther back than those flowing in the opposite direction.[2] That the main streams follow the fault lines, the writer quite agrees. And, if the faults downthrow to the west, the rest necessarily follows. But, if they are normal

[1] Am. Geol. 1898. 21:219.
[2] Jour. Geol. 10:408.

faults downthrowing to the east, as most of the proved faults of northern New York are, it is more likely that the surface tilting would be to the west. It would also seem that the streams down the fault scarp would have an advantage over those down the back slope, because of their much steeper grades, and that originally the main tributaries would be westerly flowing streams down the back slopes, but that the streams down the scarp would lengthen at the expense of the others, pushing the divides westward. If now the main streams are at successively lower levels going eastward because of step faulting, these easterly tributaries would have that additional great advantage over those flowing west, and would not only tend to extend themselves at the expense of the westerly streams, but also to work back to, and to tap and lead off portions of the larger streams to the westward. Inspection of the maps shows many such apparent captures of the main streams by the easterly tributaries. If the writer be correct in his belief that these are the main structural features of the region, the assumption of the abnormal easterly tilting of the fault blocks seems unnecessary.

The great and abnormal bends to the northeast which are made by both the Hudson and the Sacandaga, some 15 miles to 25 miles north of the Mohawk line, would seem to be wholly modern and owing to glacial action. As a result of this swerve, no stream of respectable size enters the Mohawk eastward from East Canada creek, the drainage all turning east to the Hudson, while the divide between the streams flowing south to the Mohawk and those passing east into the Hudson, parallels the Mohawk and is distant from it only 15 to 18 miles. These features are excellently shown on the new, small scale topographic map of the State and strongly suggest a morainic divide, and that the Sacandaga formerly came down to the Mohawk in the Amsterdam region. The modern stream which flows northeastward from Gloversville and empties into the Sacandaga at the big bend, would seem to occupy this valley. Obviously a considerable shifting of divides must take place here in the near future, the present arrangement being highly unstable.

Chamberlin long since urged that the preglacial divide or col in the Mohawk lowland, between the drainage east to the Hudson

and that west to the Ontario valley, was at Little Falls, the location being determined by the Precambric rock mass there, brought up by the Little Falls fault.[1] Brigham has urged that West Canada creek was, at that time, tributary to the west flowing drainage, which he names the Rome river, coming into the valley at Oriskany by way of Holland Patent.[2] While the writer quite coincides with this view, he is also disposed to the belief that this route is comparatively modern, representing a capture of the upper part of the Black river drainage by a tributary of the Rome river. Black creek, the main tributary of West Canada creek, flows along the Precambric boundary in a northwesterly course, and seems unquestionably to represent the former upper portion of the Black river, as is shown in an excellent manner on the new topographic map. There is heavy drift filling between, but no sign of any rocky col, and the tributaries from the northeast show perfect parallelism with the Black river head waters coming down from the same direction.

Youthful character of the present drainage. During the withdrawal of the Laurentide glacier from the northern Adirondacks, the preglacial stream courses cut in the valley base level were completely filled with glacial deposits, while at the same time the irregular floor of the valley base itself was covered and evened by them. After the departure of the ice, the courses of the streams were determined by the position and slope of these deposits, and some discrepancy between their present and former courses was produced. The slopes of the glacial deposits in the valleys were gentle, lakes occupied the hollows more numerously than at present, and the new streams obtained steep grades only after they emerged from the hills on the slopes leading down to the Champlain and St Lawrence valleys. Their profile was convex rather than concave, and so it remains to a large extent today, while in mature stream valleys the profile is concave.

The main streams of the region are of respectable size, and their slope is steep. The Saranac river from Lower Saranac lake to Lake Champlain, in a course of about 75 miles by the river, has a fall of over 1400 feet, nearly 20 feet to the mile. The Ausable, from Lake Placid down, has a greater fall than the Saranac

[1] U. S. Geol. Sur. 3d An. Rep't, p.362.
[2] Geol. Soc. Am. Bul. 9:191.

by 300 feet in a somewhat shorter course. The Raquette and St Regis have a slope somewhat less, but yet over 15 feet to the mile. These are considerable slopes for streams of the size, and excavation of their beds is going on at a fairly rapid rate. The drift deposits were rapidly cut into and the top of the rock knolls of the valley floors, which lay underneath the stream where it was not over its old channel, were uncovered. The rapid down-cutting would be at once checked at these points, but on the down-stream side of the obstruction the cutting in the drift would continue actively, causing a fall or rapid at the point, which would commence to saw back a gorge into the rock obstruction. Upstream, however, the drift could not be cut out to a greater depth than the level of the obstructing rock ledge, though it would be quickly worn down to that level and a wide valley rapidly eaten out in the yielding drift materials. In this way the stream courses would be divided into sections of slight declivity and of mature character, commencing and terminating with rapids over rock ridges.

Most of the Adirondack streams illustrate well these general principles. Their head waters are in chains of lakes, and their courses below consist of reaches, or stillwaters or levels as they are locally called, interrupted by rapids and gorges. The Saranac serves well as a type. It rises in Lake Clear, passes thence into Upper Saranac lake, Round lake and Lower Saranac lake and leaves the latter near the middle of its eastern side in a wholly postglacial channel. At the rapids at Saranac village the river is only 6 miles distant from Lake Clear in an air line, while by water it is from 25 to 30 miles distant. Below the village the first considerable rapid is at Franklin Falls some 20 miles away, where the river falls 40 feet within the space of half a mile. In the 20 miles above it has fallen less than 100 feet, or only about 4 feet a mile. Below the falls it flows through a gorge half a mile long, with walls 100 feet high, which apparently marks the channel of a small preglacial stream, or else a low divide between two small streams. Below the gorge a wide marshy valley opens out, through which the river flows in a beautiful series of meanders. Heavy drift filling turns it aside over the rock ledge in the gap at Union Falls. At Clayburg, 8 miles below, it meets the north branch and turns abruptly into the larger valley occupied by

that smaller stream. Turned aside, probably by depth of drift, the river encounters the ponderous rock ridge at the High falls, in which it has cut a very considerable gorge, which appears wholly postglacial. The position of the preglacial channel hereabout has not been ascertained, a fairly continuous line of rock outcrops occurring to the northward and many appearing to the south of the present channel.

Beyond the High falls the valley is again broad and filled with drift. At Cadyville the river is once more out of its old channel, and has cut quite a gorge in the Potsdam sandstone at that point. From Cadyville to the mouth of the river at Plattsburg the fall is 400 feet and the distance 10 miles, giving a rate double the average fall of the stream, yet the bottom of the drift filling is nowhere reached save at the pulp mill, 2 miles above Plattsburg, where a long but not deep cut through the Beekmantown limestones has been made, and at Plattsburg itself.

Two thirds of the 1400 foot fall of the Saranac is made in the lower one third of its course, giving a highly convex profile. The Ausable follows its old valley more closely, crosses the 1000 foot contour much farther from its mouth and has a profile not notably convex. The northwesterly streams all have convex profiles also.

The Raquette drainage shows some interesting and puzzling features. The reach from Raquette falls to Piercefield is much the longest shown by any Adirondack stream. In all this distance the valley is wide and mature, the river flows in great loops which reach the rock walls but seldom, cut-off oxbows are exceedingly common, and the valley floor is mainly one great swamp. The valley narrows to Raquette falls, where there is a fall of 70 to 80 feet in a gorge ¾ of a mile long, in which the water is rapid throughout, but with two principal falls [pl. 18]. There is an impassable rock barrier here, with no opportunity for a buried channel, so that there could have been no preglacial drainage line; rather, there was here a col between small streams flowing both ways from the obstruction. Above Raquette falls the valley widens southward, as it should on this supposition. It was occupied by a small preglacial, south flowing stream, which either

Plate 18

Main fall in the gorge at Raquette Falls. The rock is the border, gabbroid phase of the anorthosite

turned eastward into the valley running east from Long Lake village, or else westward and out through Raquette lake valley and the Moose river. The former is the more likely, though the drainage must originally have been westward, and this eastward course represents a later reversal of direction, since it crosses the main axis.

The stream flowing north from Raquette falls was a tributary to the main drainage line running westward from Axton, in the present Raquette valley, with the Ampersand creek valley as its eastward extension. Not unlikely there was a corresponding tributary from the north, occupying the present valley of Upper Saranac lake, though it is not yet certain whether that stream drained to the south into the Raquette or to the north into the St Regis. The general drainage arrangement in this district is of the trellis pattern, it being a northern extension of the southeastern area, where that type prevails, though it seems more disturbed by glacial action than that.

Lakes

Lakes are of frequent occurrence throughout the Adirondack region. They most abound in what has been called the lake belt, but they are found in great number throughout the central and western portions of the region. East of the main axis, they occur in much smaller number, though by no means infrequent. There are literally hundreds of them. They range in size from fairly large bodies of water, several miles long and a mile or two in width, down to the most insignificant of ponds. The larger ones are usually long and narrow and occupy the full width of the valley in which they lie. These are mostly confined to the central and eastern portions of the district, those portions whose main valleys have received a north to northeast alinement from the faults, and the lakes occupy portions of the main valleys, their trend coinciding with that of the valley direction. Upper and Lower Saranac, Big and Little Tupper, Indian, Schroon and Long lakes are the more prominent members of this group. Placid, Cranberry and Raquette lakes are of a somewhat different

type, in that they seem to occupy portions of more than one valley, the valleys being closely adjacent and the divides low, and their greater breadth being thus accounted for. There are rock islands, in fact, in all of these large lakes and often in considerable number. Lower Saranac lake is full of them, alined so as to suggest the drowning of adjacent small valleys. The chain of islands in the center of Big Tupper lake suggests the same thing.

The smaller lakes are of a great variety of types. Some of them are in narrow and some in wide valleys; some are nearly or wholly rock bound, while others show little or no rock along their shores; some are in deep, steep sided valleys, while others have low, sloping shores; some are strung out in chains along a single valley, though the majority are single.

The causes for the existence of these lakes are as various as the causes which produce hollows on the surface of a region recently invaded by an ice sheet, such a surface having a combination topography due to both destructive and constructive processes. It is held by many observers that locally glaciers may excavate shallow rock basins, and Ogilvie has argued that lake basins of that type are abundant in Hamilton county.[1] Quite likely also such exist in the north portion of the region, though they certainly are not the common type there, the majority occupying depressions in the drift surface in the wider valleys. Such a lake as that shown in plate 16, for example, is a good representative of the usual type. This lake, Stony Creek pond, shows occasional rock ledges on its east shores, but it lies on the east edge of a great sand terrace which extends from the south end of Upper Saranac lake to Axton on the Raquette, the sand undoubtedly overlying till at no great depth, so that we are dealing with a small preglacial valley now badly clogged with drift. The level of the pond is so nearly that of the modern Raquette at Axton that its outlet has no cutting power.

The larger lakes are mostly up near the main divide of the region; and, though they occupy portions of preglacial valleys, these were toward the head waters of the preglacial streams and were therefore of no great width. Their south to southwest

[1] *Op. cit.*, p.411.

trend closely conforms to the direction of movement of the ice sheet, which must thus have thoroughly scoured them, and it may well be that some, or all, of them have somewhat of the rock basin character, though no proof of this is yet at hand, so far as the writer is aware. Many of them are demonstrably held up by morainic dams; but that might be true and yet the lake be somewhat of the rock basin type. Many have highly irregular shore lines, owing to the drowning of the mouths of the small, tributary valleys, and in general there are no features of these which at all suggest the hanging valley type; they rather strongly suggest the contrary. In the comparatively small number of instances of what may prove to be hanging valleys, of which Bog river falls at the upper end of Big Tupper lake is a good example, it is far from certain that the streams are not locally out of their preglacial channels near their mouths, and that the fall is not thus to be accounted for. There are however some features of these larger lakes that do suggest some deepening of their basins by the ice sheet, but the data are too fragmentary to justify a present discussion.

Many of the Adirondack lakes are being shallowed quite rapidly by the considerable amount of sediment washed into them by the streams. In the few thousand years that have passed since the ice vanished from the region quite a number of lakes, both large and small, have been completely filled in this way and converted into vleis. And at the present day many examples showing all stages of the process are to be found.[1] Some are converted into comparatively dry meadows, some are wet and boggy, some have still a foot or so of water, but with a growth of vegetation over the entire surface, others have still some clear water in the center, others only a fringe of rushes and water lilies along their margins, still others are very shallow throughout but with only a beginning of vegetable growth, and this well out in the pond as well as near shore, yet others are still comparatively deep. Almost without exception the topographic sheets of the region show examples, and often numerously. On the Saranac lake quadrangle, for example, a filled lake basin, 4 miles long, is seen in the north center of the sheet,

[1] *See* Smyth, C. H. jr. Lake Filling in the Adirondack Region. Am. Geol. 11:85–90.

its flat surface being utilized by the Chateaugay Railroad for a roadbed, while Sumner creek works its sluggish way through it in a beautifully typical, meandering course; Ray brook may be seen flowing through a small, filled pond on the southeastern part of the map; on the extreme southwest, the marsh which fills the former east portion of Middle Saranac, locally called Round lake, is well shown; on the northwest, the Osgood river flows into the pond of the same name through a swamp which marks its filled northern extension; the south end of Colby pond is converted into a marsh; on the other hand, Lower Saranac and Rainbow lakes, Mackenzie, Moose and Lonesome ponds are not yet sufficiently shallowed anywhere to show more than a mere beginning of marsh vegetation. On the Blue mountain quadrangle there are fewer examples, but Polliwog pond, on the extreme north and just east of Long lake, is marsh except for the small lagoon yet remaining in the center; Rock lake is marsh at the west; and the Grassy ponds, on the east near the Chain lakes, have names which imply their condition. These are but two examples selected at random from among the 20 Adirondack sheets so far published. Any of the remainder would have served equally well. Those lakes originally the shallowest, and those into which sediment is being, or has been washed the most rapidly, are of course those in the most advanced stage.

According to Ries, while lake filling is going on at many points in the Adirondack region, yet very little true peat seems to have been formed, for the streams flowing into the lakes often carry too much sediment, and plants other than mosses usually fill up the lake.[1]

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[1] N. Y. State Geol. 21st An. Rep't. 1903. p.r85.

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The superior figures tell the exact place on the page in ninths, e. g. 331^3 means page 331, beginning in the third ninth of the page, i. e. about one third of the way down.

New York State Education Department

New York State Museum

PUBLICATIONS

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Museum annual reports 1847-date. *All in print to 1892, 50c a volume, 75c in cloth; 1892-date, 75c, cloth.*

These reports are made up of the reports of the director, geologist, paleontologist, botanist and entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Geologist's annual reports 1881-date. Rep'ts 1, 3-13, 17-date, O; 2, 14-16, Q.

The annual reports of the early natural history survey, 1837-41, are out of print.

Reports 1-4, 1881-84, were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

Separate volumes of the following only are available.

Report	*Price*	*Report*	*Price*	*Report*	*Price*
12 (1892)	$.50	17	$.75	21	$.40
14	.75	18	.75	22	.40
15, 2v.	2	19	.40	23	*In press*
16	1	20	.50		

In 1898 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1899-1903. The two departments were reunited in 1904.

Paleontologist's annual reports 1899-1903.

See fourth note under Geologist's annual reports.

Bound also with museum reports of which they form a part. Reports for 1899 and 1900 may be had for 20c each. Those for 1901-3 were issued as bulletins. In 1904 combined with geologist's report.

Entomologist's annual reports on the injurious and other insects of the State of New York 1882-date.

Reports 3-19 bound also with museum reports 40-46, 48-57 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3-4 are out of print, other reports with prices are:

Report	*Price*	*Report*	*Price*	*Report*	*Price*
1	$.50	9	$.25	15 (En 9)	$.15
2	.30	10	.35	16 (" 10)	.25
5	.25	11	.25	17 (" 14)	.30
6	.15	12	.25	18 (" 17)	.20
7	.20	13	.10	19 (" 21)	.15
8	.25	14 (En 5)	.20	20 *In press*	

Reports 2, 8-12 may also be obtained bound separately in cloth at 25c in addition to the price given above.

Botanist's annual reports 1867-date.

Bound also with museum reports 21-date of which they form a part; the first botanist's report appeared in the 21st museum report and is numbered 21. Reports 21-24, 29, 31-41 were not published separately.

Separate reports 25-28, 30, 42-50 and 52 (Botany 3), are out of print. Report 51 may be had for 40c; 53 for 20c; 54 for 50c. Since the 55th these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have been published in volumes 1 and 3 of the 48th museum report and in volume 1 of the 49th, 51st, 52d, 54th and 55th reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum memoir 4.

Museum bulletins 1887–date. O. *To advance subscribers, $2 a year or 50c a year for those of any one division: (1) geology, economic geology, mineralogy, (2) general zoology, archeology and miscellaneous, (3) paleontology, (4) botany, (5) entomology.*

Bulletins are also found with the annual reports of the museum as follows:

Bulletin	*Report*	*Bulletin*	*Report*	*Bulletin*	*Report*	*Bulletin*	*Report*
G 1	48, v.1	Pa 1	54, v.1	En 7–9	53, v.1	Ar 3	52, v.1
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3	52, v.1	4	" v.4	11	" v.3	5	" v.3
4	54, v 4	5, 6	55, v.1	12, 13	" v.4	6	55, v.1
5	56, v.1	7–9	56, v.2	14	55, v.1	7	56, v.4
Eg 5, 6	48, v.1	Z 3	53, v.1	15–18	56, v.3	Ms 1, 2	" v.4
7	50, v.1	4	54, v.1	Bo 3	52, v.1		
8	53, v.1	5–7	" v.3	4	53, v.1	*Memoir*	
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10	" v.3	9	56, v.3	6	56, v.4	3, 4	53, v.2
11	56, v.1	En 3	48, v.1	Ar 1	50, v.1		
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